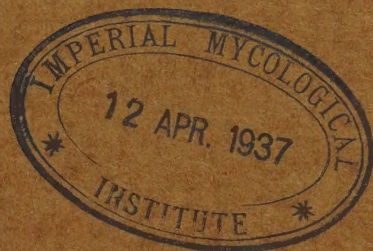


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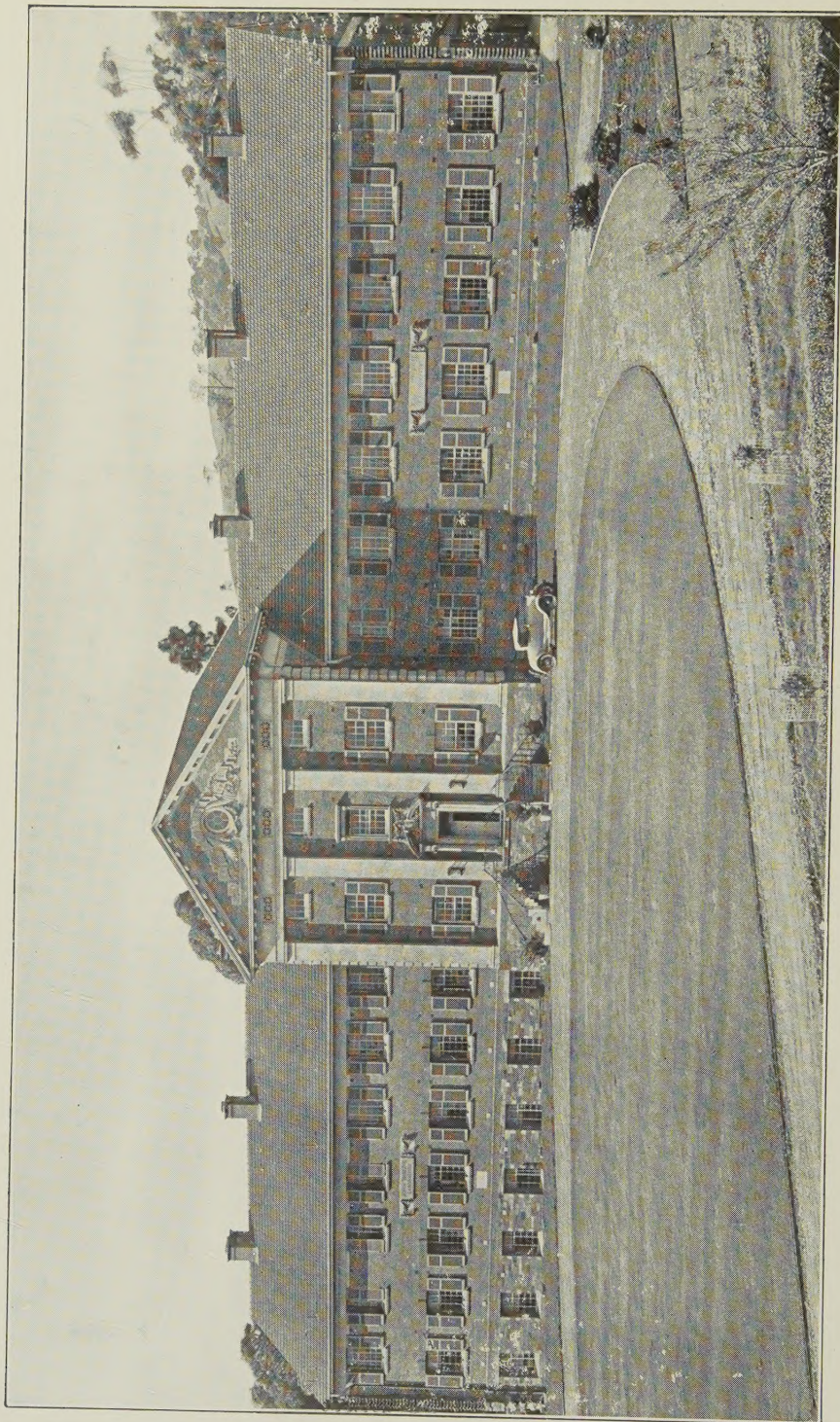


REPORT
OF THE
WAITE AGRICULTURAL
RESEARCH INSTITUTE

GLEN OSMOND, SOUTH AUSTRALIA

1933-1936

ADELAIDE
AT THE HASSELL PRESS
1937



THE LABORATORIES OF THE WAITE AGRICULTURAL RESEARCH INSTITUTE.

University of Adelaide



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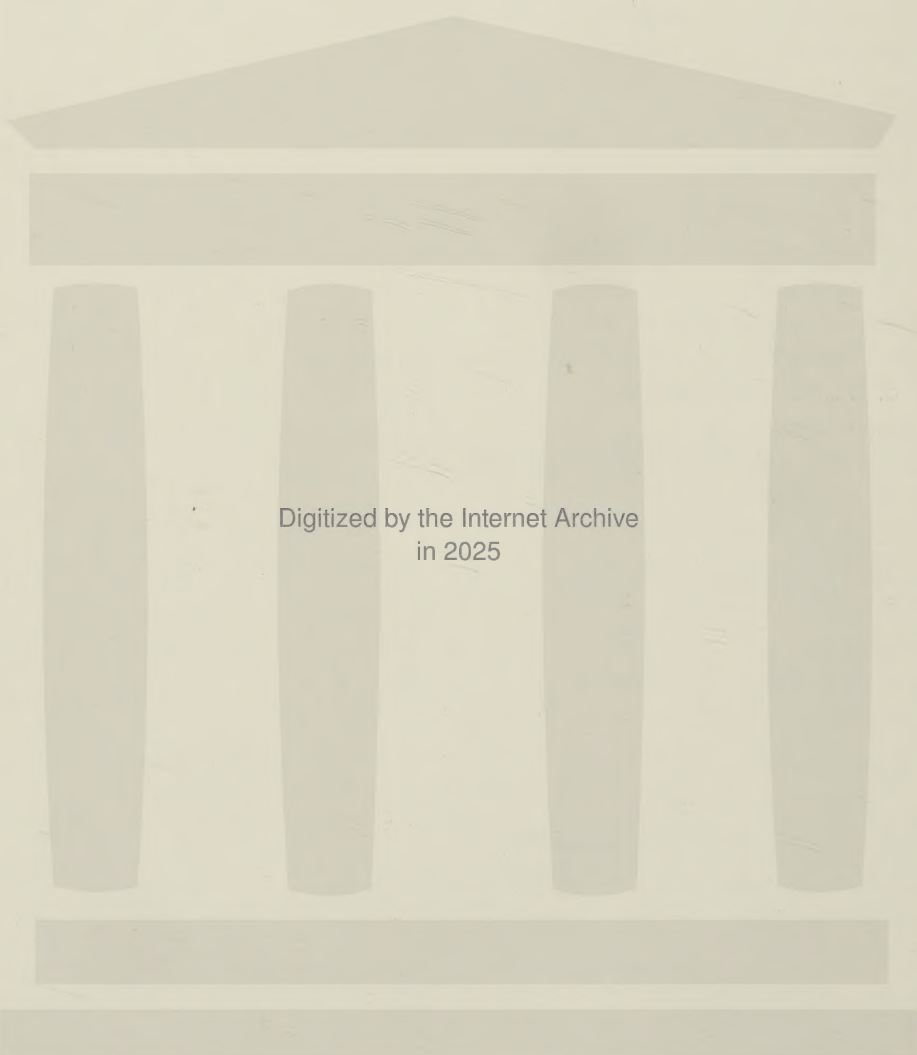
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The Waite Agricultural Research Institute

1. INTRODUCTION.

The Waite Agricultural Research Institute was established as a result of the late Mr. Peter Waite's gift to the University for the purpose of furthering the cause of education and research in agriculture and allied subjects. The endowment comprises the Urrbrae, Claremont and Netherby estates, consisting of 299



Waite Agricultural Research Institute taken from eastern boundary of the property, 1936.

acres of agricultural and grazing land situated at Glen Osmond, of a mansion house, and a Trust Fund of £58,450. The total value of the bequest was estimated at £100,000.

The estate lies on the scarp of the Adelaide foothills, within four miles of the city of Adelaide. Portion of the estate comprises wheat land, 280–390 feet above sea level, whilst the remainder is representative of the hilly country at the foothills of the Mount Lofty Ranges.

The University Council decided that the best means of giving effect to the wishes of the donor would be to establish an Agricultural Research Institute and endeavour to enlarge the stock of knowledge relating to agriculture in the widest sense, and pass it on to those actively engaged in production, as farmers or pastoralists. Moreover, the Council decided that for the present the investigations should be confined to plant and soil problems, and to the insect and fungus pests of farm crops. It also appointed its Finance Committee to act as its Board of Management.

The active work of the Institute began in March, 1925. The initial task was the gradual conversion of a large suburban estate into a modern Agricultural Research Station. As the funds available at the inception of the Institute were insufficient to erect and equip the necessary permanent buildings, laboratories were improvised in the existing buildings on the estate, pending the erection of permanent structures.

Sixty acres of arable land on the Urrbrae estate and eleven acres of land on Netherby estate were cleared, and converted into permanent experiment fields for the investigation of problems relating to the production of farm crops and improvement of crops and pastures.

A meteorological station and a system garden, containing upwards of 200 species of indigenous and exotic fodder plants, were established in 1925.

A pot culture house, 80 feet by 18 feet, was erected in 1925 to carry out investigations on the water requirements of farm crops.

Practically the entire farming plant required for the initial development of the field investigations came as gifts from agricultural implement makers, and a stone implement shed, 90 feet by 30 feet, was erected to accommodate these implements.

During 1926 the Council for Scientific and Industrial Research, in co-operation with the Waite Institute, undertook to investigate the cause of the tomato wilt disease. The Council erected an insect-proof glasshouse for the purpose of this investigation.

In 1927 the Empire Marketing Board, in co-operation with the Council for Scientific and Industrial Research and the University of Adelaide, jointly agreed to provide funds for the investigation of the mineral content of pastures in Australia. The Empire Marketing Board agreed to contribute a grant of £3,000 towards a laboratory and a sum of £1,875 per annum for a period of five years for this co-operative investigation. The Council for Scientific and Industrial Research contributed £3,000 towards a laboratory for the investigation of the mineral content of pastures and the soil problems associated with the Murray River settlements, and a sum of £937 per annum towards the maintenance costs of the former investigation. When the Empire Marketing Board was disbanded the Trustees of the Carnegie Institution of New York provided funds amounting to £2,650 over a two-year period for the maintenance of these pasture investigations, provided

that the University undertook to continue the investigations subsequent to the expiry of the grant.

Through the generosity of Sir John Melrose of Ulooloo, who, in 1927 gave £10,000 to the University for the building of a laboratory, the University was able to construct the first group of permanent laboratories for the Institute. The foundation-stone of the John Melrose Laboratory was laid by Miss Lily M. Melrose, daughter of the donor, on January 26, 1928. The building was formally declared open by His Excellency the Governor of South Australia, Sir Alexander Hore-Ruthven, V.C., on April 22, 1929. Mr. J. T. Mortlock, of Martindale Hall, contributed a sum of £2,000 to the University for the equipment of the laboratories.

A field station was established at the Waite Institute in 1927 by the Council for Scientific and Industrial Research for the investigations of problems relating to Animal Nutrition. Associated with the field station is a series of sixty pens for feeding sheep, and a metabolimeter room.

In December, 1927, the Parliament of South Australia passed the Agricultural Education Act, which provides for an appropriation for a period of ten years to the University for the development of agricultural research at the Waite Institute. Under the terms of the Act, the University was required to maintain a School of Agricultural Science of degree standard, and to undertake specific investigations in agriculture and allied subjects, and to provide for advisory services in Plant Pathology and Entomology to the Minister of Agriculture. These services were provided by the University.

In 1928 the Imperial Chemical Industries Limited agreed to provide a sum of £2,000, spread over three years, for the investigation of the effect of nitrogenous fertilizers; in 1931 and 1932 it made further contributions of £666 13s. 4d. and £300 respectively, and since then £500 a year for the same purpose.

In 1928 the Government of South Australia, through the Education Department, granted to the Waite Institute the use, for agricultural and grazing investigations, of 115 acres of arable land, given by Mr. Peter Waite to the State for the establishment of an Agricultural High School. This area adjoins the Waite Institute, and has been subdivided and developed for the purpose of conducting investigations on farm crops, natural grassland and seeded pastures.

In 1929 the Commonwealth Bank of Australia agreed to provide a sum of £2,500 conditionally upon the University providing a similar sum towards the cost of a group of buildings, comprising an insectary for the investigation of entomological problems, a plant culture house for investigations in plant physiology, and a laboratory to provide facilities for a range of four glasshouses. The buildings were completed in November, 1929, and were officially opened by R. B. McComas, Esq., a Director of the Commonwealth Bank of Australia, on December 9, 1929.

In June, 1929, Mr. Harold Darling gave £10,000 to the University on behalf of the family of the late Mr. John Darling, for the building of a Soil Research Laboratory at the Waite Institute. The Council for Scientific and Industrial Re-

search agreed to provide the equipment and maintenance of this laboratory and, jointly with the University of Adelaide, to establish a Division of Soils under the direction of Professor J. A. Prescott, at the Waite Institute.

The foundation-stone of the John Darling Laboratory was laid by His Excellency the Governor of South Australia, Sir Alexander Hore-Ruthven, V.C., on April 14, 1930. The laboratory was formally declared open by His Excellency the Governor-General of Australia, Lord Stonehaven, on September 16, 1930.

Under the will of Mrs. Elizabeth Macmeikan, widow, and daughter of the late Mr. Peter Waite, who died on April 5, 1931, her residuary estate, after payment of certain bequests, was left in trust to the University of Adelaide. The net income in the residuary estate is to be paid to the University in perpetuity for establishing and maintaining the study of agriculture, botany, zoology, veterinary science, entomology, horticulture and forestry by the University, either in connection with the Waite Agricultural Research Institute or otherwise.

In August, 1936, the family of the late Mr. Frederick Ranson Mortlock offered the Council of the University the sum of £25,000 for research work in connection with soil erosion and regeneration of pastures on pastoral lands. The conditions attaching to the gift, which was contributed equally by Mrs. Rosye F. Mortlock (the late Mr. Ranson Mortlock's mother) and his brother, Mr. John T. Mortlock, were as follows:

1. The gift to be known as the "Ranson Mortlock Trust" for "Research work in connection with soil erosion and regeneration of pastures on pastoral lands."
2. A suitable building to be erected at the Waite Institute for the purpose of the Trust, such building to cost not less than £10,000 and to be named the Ranson Mortlock Building.
3. The preparatory work under this Trust to be commenced within a period of three months, and building operations before the expiry of eighteen months from the date of the gift.

The conditions were accepted by the University, and the necessary preparatory work, as specified in the deed of gift, begun.

In 1936 the Council for Scientific and Industrial Research provided the Institute with a Ford V8 Utility Truck to enable survey tours of the State to be conducted in connection with the investigation on the plague grasshopper problem. The Department of Agriculture of South Australia also co-operating in this investigation agreed to pay the daily maintenance allowance of the investigator when on the necessary surveys, and also the maintenance costs of the truck.

2. THE JOHN MELROSE AND JOHN DARLING LABORATORIES.

The John Melrose and John Darling Laboratories form respectively the south-central and north-central wings of the laboratories designed for the accommodation

of the research staff. The buildings face west, with a fine outlook over the city and suburbs of Adelaide and over the Gulf of St. Vincent.

The central block comprises a large entrance hall, offices, temporary library, common-rooms for the staff, photographic room, and a basement. The basement has two rooms, one of which, designed to afford a minimum variation in temperature, is devoted to physico-chemical work, and the other accommodates a large dehydrator for the rapid drying with low pressure steam of large numbers of samples of plant material.

On October 31, 1936, there were 2,955 bound volumes in the library. Subscriptions have been made to a further 20 scientific periodicals during the last three years, bringing the number now received to 80. These are displayed, together with other material presented to the library, for the perusal of the staff before being circulated amongst interested members.

An exchange of publications with Government Departments, Agricultural Experimental Stations, and other research stations, has been instituted. There are



Interior view of glasshouse used for water requirement investigations of field crops and pasture plants.

now 200 names on the mailing list, and to these copies of approximately 170 papers contributed by members of the staff have been forwarded.

The Melrose Laboratory contains two floors, the ground floor devoted to agronomic and botanical work, and the first floor to chemical work.

The John Darling Laboratory is practically a replica of the John Melrose Laboratory, except that it has a basement, comprising rooms and laboratories for instructional work for the degree of B.Ag.Sc.

Provision has been made in the building plan for further extensions of the laboratories as the need arises and as the work of the Institute develops, by the erection of wings adjacent to the Melrose and Darling Laboratories. The present accommodation provides 24,700 square feet of floor space.

3. FARM BUILDINGS AND PLANT HOUSES.

The farm buildings comprise a cereal and grain storage house, 96 feet by 30 feet, constructed of brick with tiled roof, two stone implement sheds, 90 feet by 30 feet, stables for the accommodation of eight horses, and four cottages for farm labourers.

The group of plant culture houses, situated in an enclosure to the south of the John Melrose Laboratory, comprises a range of four glasshouses, 81 feet long by 24 feet wide, and a plant culture laboratory to serve the needs of these for preparation, storage, and laboratory accommodation. Of these glasshouses, two are used for plant physiological and agronomic investigations, one for plant pathological, and one for entomological work.

4. SCIENTIFIC WORK OF THE INSTITUTE.

The main objective of the Institute is to enlarge the stock of knowledge relating to agriculture in the widest sense and to pass it on to those actively engaged in production, as farmers or pastoralists. Expressed in more precise terms, the aim is to conduct researches on plant and soil problems relating to agriculture, and on the insect and fungus pests which affect production.

The Institute also provides an advisory service to the Department of Agriculture in Plant Pathology and Entomology. The University of Adelaide maintains a School of Agricultural Science and courses of instruction for the degrees of B.Ag.Sc. and M.Ag.Sc. Specialized courses of instruction in agriculture, agricultural chemistry, plant pathology, and entomology for these degree courses are provided at the Waite Research Institute.

Though extension work in agriculture is not a function of the Institute, a considerable amount of educational work in agriculture is effected through visits of Agricultural Bureaux, parties of farmers, and other visitors, to the experimental fields and laboratories.

The scientific work of the Institute comprises the following :

Agriculture and Plant Problems.

The investigation of the problems affecting the production of farm crops; the improvement of pastures; ecological and plant nutrition studies of pasture plants; the improvement of cereals and fodder plants by hybridization and selection; the investigation of problems of mineral metabolism and the relation of nutrition to plant growth.

Agricultural Chemistry and Soil Research.

The survey and classification of Australian soil types; the investigation of fertility problems, particularly in the irrigation settlements; and the chemical study of the nutritive value of pastures, with special reference to mineral constituents.

Entomology.

Investigation of the insect pests affecting agricultural and horticultural crops.

Plant Pathology.

Investigation of the diseases of agricultural crops, with particular reference to the spotted wilt disease of tomatoes, manganese deficiency disease of oats, and take-all and foot-rots of wheat.

The Work of the Institute

Agriculture and Plant Problems

The most fundamental part of agriculture is the production of crops and pastures, and the researches are directed mainly to the investigation of the principles underlying the practice of farming in a winter rainfall climate, including the tillage of the soil, the manuring of crops and grassland, the rotation of crops, the establishment of pastures and their utilization by the grazing animal, and the production of improved varieties and strains of farm crops and pasture plants.

Approximately 81 per cent. of South Australia has a rainfall of less than 10 inches, and this area is devoted exclusively to pastoral pursuits. Over the remaining portion of the State, comprising the agricultural area, the rainfall varies from 10 to over 30 inches. The winter incidence of the rainfall is suitable for the production of cereal crops, but except in the moister regions the dry summer period is unfavourable for the maintenance of permanent pastures of the British herbage species.

The most important agricultural problem is therefore the development of a system of cereal culture and grassland management which will make the utmost use of the seasonal rainfall, and which will be adapted to the exigencies of a semi-arid climate. The results may be applied broadly to a considerable area of country in the winter rainfall zone of Australia.

1. FIELD CROP INVESTIGATIONS.

(1) *Water Requirements of Crops.*

The investigation of the factors affecting the utilization of water by agricultural plants is of particular importance in regions where rainfall limits the production of crops and pasturage. Water requirement investigations have been conducted with farm crops and a number of typical indigenous and exotic pasture species to determine the factors affecting their water economy under cultivation. The results of these investigations are recorded in another section of this report (p. 91).

The amount of rainfall required to produce a given weight of dry matter in pasture plants was found to vary from season to season. These differences in the transpiration ratios were shown to be due to variations in the intensity of the environmental factors, particularly air temperature, saturation deficit of the air, wind movements, throughout the active growth period, but particularly during the critical period of maximum growth and transpiration which normally occurs for crop and pasture plants in Adelaide in October.

A close correlation was found to exist between the rate of transpiration of crops and pastures and the rate of evaporation from a free water surface during this period. Moreover the effectiveness of the rainfall was lowered by unfavourable factors such as, high air temperature, low atmospheric humidity, and high wind velocity during the period of maximum transpiration.

The investigation revealed that the use of improved varieties of wheat, barley, peas, and subterranean clover, with early-maturing habit and high ratio of seed to total produce offered a means of adapting the crop to a semi-arid environment. Thus the discovery of early-maturing strains of subterranean clover capable of producing seed under dry spring conditions has greatly extended the subterranean clover belt in Southern Australia.

Liberal dressings of soluble phosphates were found to accelerate early growth and to lower the water requirement of all types of farm crops for grain production. With pasture plants the yields of dry matter were increased materially by the use of superphosphate, and the water requirement substantially reduced, particularly in the early stages of growth.

The application of nitrogen to Wimmera rye-grass grown on soil in which cereals preceded the grass, led to a substantial reduction in the amount of water required to produce a unit of dry matter.

Soluble phosphates were found to be particularly effective in reducing the water requirements of pasture plants in the early stages of growth. This is of particular significance in the rotational grazing of pastures by livestock.

Over a period of eight years it was found that for each inch of rain transpired by the crop an average of 3·3 bushels of wheat and 5·5 bushels of barley may be produced. The mean effective rainfall during the growing period of the crop in South Australia is approximately 11 inches, and the average yield for the State for ten years is slightly less than 1 bushel of wheat and 1·6 bushels of barley per inch of seasonal rain. If due allowance be made for the increased severity of the environmental factors in less favoured portions of the State, it should be possible to increase greatly existing yields of wheat and barley before the limits imposed by the rainfall are approached.

(2) *Permanent Rotation Experiments.*

The conduct of field experiments over fairly long periods is essential to obtain decisive information concerning the possible methods of improving agricultural practice. Differences in yields due to crop rotation, manuring, methods of cultivation, varieties, and time of sowing, are always influenced by the accompanying phenomena—rainfall and its incidence, evaporation rate during critical periods, diseases or pests, etc.—which are liable to change from season to season. Only an average yield of a period of years can be decisive in determining the systems of cultivation, rotation and fertilization best adapted for a given environment.

A series of permanent rotation plots was established in 1925 to determine the

yield of wheat grown under various systems of rotation cropping in the Adelaide plains environment. The rotation series may be described as a miniature test of different systems of growing wheat, and as far as possible the cultural treatment for each crop in the rotation series is the same as it would receive if grown on a large area.

The normal cultural practice in the wheat belt is to precede the wheat crop with a well-worked bare fallow, and to include, according to circumstances, oats, barley, or temporary pasture in the rotation. In the higher rainfall areas peas or fodder crops fed off with sheep are used in rotation with wheat.

Eleven rotation systems have been tested over the period 1926–1936. The value of these rotational systems can only be determined by their long-term effect on the wheat yield and on the crops grown in rotation with wheat. The results for the years 1926–35 are summarized on p. 156.

In six of the rotation cropping systems the main crop (wheat) is preceded by a well-worked fallow. The average yield of wheat for this group is 38·9 bushels per acre for the ten-year period. Two rotations in which the land has been continuously cropped for ten years with wheat, barley, peas; and wheat, oats, peas, have given the following yields:

- (a) Wheat 34·02 bush., Barley 48·46 bush., and Peas 25·85 bush. per acre.
- (b) Wheat 32·74 bush., Oats, 45·61 bush., and Peas 25·38 bush. per acre.

The rotation which has consistently shown the highest yield of wheat is the four-course rotation, in which only two cereal crops are grown in four years, namely, wheat, oats, pasture, bare fallow, the ten-year averages for which are:

Wheat 44·38 bushels, Oats 59·87 bushels, and
Wimmera rye-grass hay 32·93 cwt. per acre.

On the other hand the yield of wheat grown continuously on the same land for ten years has averaged 17·03 bushels.

Difficulty has been experienced in recent years in maintaining the rotations free from weeds. Rotations in which the land has been cropped continuously throughout the ten-year period are noteworthy in this respect.

(3) *Permanent Fertilizer Tests.*

Artificial fertilizers play an important part in increasing the productivity of cereal crops. In the past attention has been concentrated almost entirely on water-soluble phosphates which have given substantial increases with cereals throughout the wheat belt, and on pastures in the higher rainfall areas.

A series of permanent tests with artificial fertilizers was established in 1925 to determine the immediate and cumulative effect on wheat and barley of varying quantities of soluble phosphate, equivalent dressings of phosphatic fertilizers in the form of superphosphate, basic slag, bonedust, and supplementary dressings of nitrogen, lime and potash. Three groups each of thirty plots were sown with wheat, oats and barley, and each plot has received the same manurial treatment each time the plot has been sown.

The most significant increases in yield were obtained from superphosphate. The unmanured controls averaged for ten years 25·94 bushels of wheat, 36·05 bushels of barley, and 55·18 bushels of oats. Increasing dressings of soluble phosphate gave increasing yields of wheat and barley up to the highest dressing tested, namely, 280 lb. superphosphate per acre, but with oats there was no material increase beyond 140 lb. per acre.

The average increases in yield per acre with 187 lb. of superphosphate for ten years were: Wheat 13·08 bushels, barley 14·75 bushels, and oats 4·55 bushels per acre. Superphosphate thus had a most marked effect on the grain yield of wheat and barley.

Apart from the influence of heavier dressings on grain yields, the indirect effect of the heavier applications in promoting growth on the stubbles is important. Liberal dressings of superphosphate tend not only to give the maximum yield of wheat possible on the rainfall, but they also stimulate the growth of leguminous plants, principally *Medicago* and *Trifolium* spp., e.g. burr clover, cluster clover, on the stubble, and increase the stock-carrying capacity of the farm and the fertility of the soil.

The most marked effect was the stimulus given to the early growth of the crop and to the tillering of the wheat plants. A census count of the number of tillers on unmanured and heavily manured wheat (280 lb. superphosphate per acre) revealed that the production of tillers was increased by nearly 50 per cent. on the phosphate plot, as compared with the unmanured control. As the number of grains per head and the size of the grain were almost identical on the unmanured and the phosphate-treated plots, the increase in yield due to soluble phosphates was due mainly to the increase in the number of ear-bearing tillers.

An interesting fact which emerged was that superphosphate must be drilled in with the seed to get the full benefit of the phosphate dressing. By drilling superphosphate with the seed the yield was increased by 3·3 bushels per acre, in comparison with the same quantity of superphosphate sown with the drill on the surface of the soil after the seed had been drilled.

Equivalent quantities of phosphoric acid were applied in the form of superphosphate, basic slag, and bonedust. Superphosphate and basic slag, over a period of ten years, gave approximately the same increases in yield both for wheat and barley. On the other hand, phosphate in the form of bonedust gave considerably less wheat and barley than equivalent quantities of phosphate applied as superphosphate and basic slag.

Lime applied at the rate of 1 ton per acre every four years, i.e. equivalent to 5 cwt. per acre a year, gave a substantial increase in yield both for wheat and barley over the corresponding plots without lime. The increases due to the application of lime were 3·36 bushels of wheat and 7·08 bushels of barley per acre over a ten-year period. Oats gave no significant response to lime.

Nitrogen applied either as nitrate of soda or sulphate of ammonia at the rate

of $12\frac{1}{2}$ lb. nitrogen per acre (equivalent to $\frac{1}{2}$ cwt. sulphate of ammonia) gave no appreciable response over a ten-year period with wheat, which, however, was sown on fallow each year, but the average yield of barley was increased by about 6 bushels per acre.

The results of these tests over a ten-year period indicated that definite responses to soluble phosphate and lime were obtained with cereals, and to nitrogen whenever oats and barley followed a wheat crop.

At the completion of the ten-year period the opportunity was taken to re-design the manurial tests with a view of obtaining more precise information as to the effect of phosphorus, nitrogen and lime applied singly and in combination, each at three different levels, to wheat, barley and oats, when grown in the following rotations: (1) wheat, oats, temporary pasture, fallow; (2) wheat, barley, temporary pasture, fallow.

(4) *The Effect of Nitrogenous Fertilizers on Cereals.*

Owing to the remarkable response of Australian soils to soluble phosphates, the problems relating to the use of phosphates have been intensively studied, and in most districts the application of superphosphate, equally with the use of a well-prepared fallow, is regarded as a standard procedure for growing a good wheat crop. The practice of growing wheat after a bare fallow has obscured to some extent the merits of nitrogenous fertilizers for crops normally sown on stubble, e.g. barley and oats.

The precise physical, chemical and biological changes which take place in a soil during the process of bare fallowing are incompletely known. Investigations, however, have shown that a fallow soil normally contains considerably more nitrate nitrogen at the end of the fallowing period than at the beginning, and that nitrification is particularly active during the early summer and autumn. By seed time the amount of nitrate nitrogen found in the surface layers of a worked fallow in the South Australian environment is sufficient to meet the needs of prolific wheat crops. On the other hand, the conditions in stubble-ploughed land are very different. The available nitrogen, and incidentally the soil moisture, have been practically exhausted by the previous season's crop, and the conditions in the stubble soil during the dry summer are not favourable for nitrification. Hence the nitrate nitrogen content of a stubble soil rarely contains sufficient nitrates to meet the requirements of a good cereal crop, and the application of a nitrogenous fertilizer to a stubble-ploughed soil removes one important limiting factor.

The fallow soil normally contains more moisture at seeding than the stubble-ploughed soil, but the difference between the fallow and the stubble in moisture content is not as great as is generally supposed. For example, over a period of four seasons the difference between the moisture content of the fallow and stubble to a depth of 3 feet at the normal seeding period (June) at the Waite Institute was found to be 1.5 per cent., equivalent to a little more than half an inch of rain.

This difference in moisture content appears to be of small importance compared with the lack of nitrates in the stubble-ploughed soil, and this view is confirmed by a comparison of the effects of varying quantities of sulphate of ammonia on the yield of wheat over a period of five years (*vide* page 158), and oats and barley for three years (*vide* pages 160 and 161).

Wheat.

So far as wheat is concerned, results over a five-year period show that nitrogenous fertilizers do not give profitable responses either for hay or for grain when the crop is sown on fallow. This might be expected from the comparatively high nitrate nitrogen content of the fallow at seed time. When, however, the wheat is sown on stubble land an application of 1 cwt. sulphate of ammonia increased the yield of hay by 9.9 cwt., and the grain yield by 5.4 bush. per acre, over a period of five years. The profit resulting from sulphate of ammonia will depend upon the relative prices of hay and grain on the one hand, and sulphate of ammonia on the other.

The normal practice in the older settled areas of the wheat belt is to precede the wheat crop by a bare fallow, which, as has been shown above, does not respond to nitrogen, but in many instances, especially in the better rainfall country, wheat may be grown on stubble land, in which case the shortage of nitrogen may limit production, and applications of nitrogen should prove beneficial.

Barley.

Wheat occupies a dominant position in South Australian agriculture. It provides the main source of income for thousands of farmers, and the success of the crop largely influences the financial position of the grower. It is not unnatural, therefore, to find that wheat receives preferential treatment in respect to cultivation over other cereals. Whatever bare fallow is available is rightly devoted to wheat, and oats and barley are almost invariably, and necessarily, sown on land more or less hastily prepared from stubble and grass.

Investigation has shown that at harvest the moisture content of the soil under the wheat crop is reduced below the wilting point, and all but a small portion of the nitrate nitrogen has been used up by the crop. The dry soil conditions which normally follow the harvest in the South Australian environment are unfavourable for fresh supplies of nitrate nitrogen to be formed in the soil until the seasonal break in the weather occurs in the late autumn, and the soil becomes thoroughly moistened. Consequently oats and barley grown on such stubbles, especially in the better rainfall areas, cannot produce heavy yields, because of the lack of available nitrate in the soil. If, however, the nitrates are supplied in the form of fertilizer it is frequently possible to raise the yield, particularly of barley, to a level approaching that which would be obtained on a bare fallow.

The effect of nitrogen, applied as sulphate of ammonia, to barley when grown on stubble, has been very marked under Waite Institute conditions for three consecutive seasons, 1933-35. The results are given in detail on page 161, and show that when adequate dressings of superphosphate (2 cwt. per acre) are applied to stubble land the increased yield per acre due to an application of 1 cwt. of sulphate of ammonia increased the grain yield by 16·55 bushels per acre, and a 2 cwt. application increased the yield by 29·06 bushels per acre.



Effect of 2 cwt. Sulphate of Ammonia on oats grown after wheat, Waite Institute, 1934.

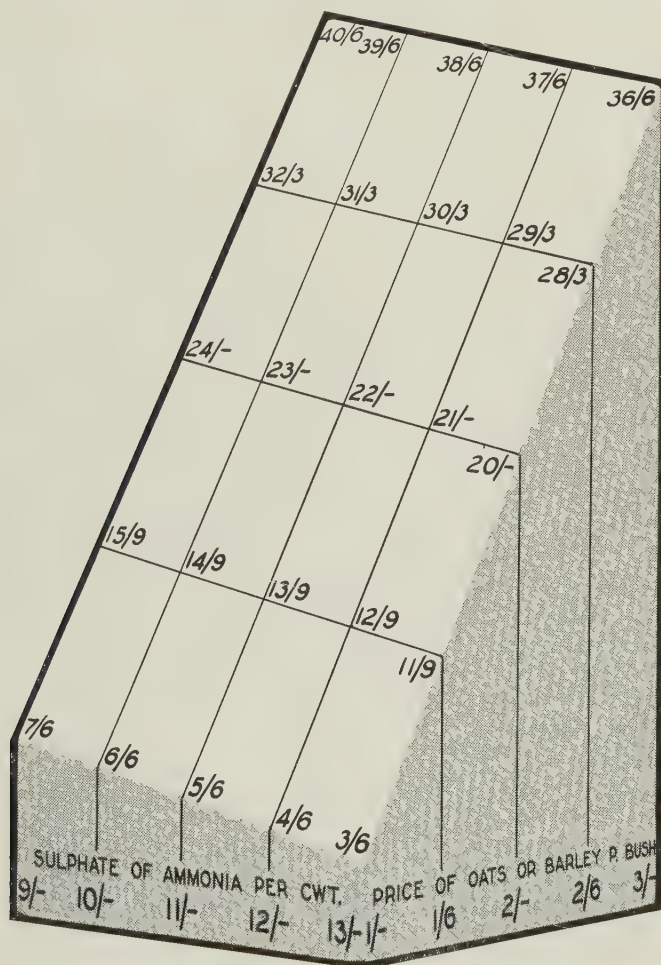
Oats.

Almost identical results have been obtained from the application of sulphate of ammonia to oats when sown after wheat. The details are given on page 160, and show that when adequate dressings of superphosphate (2 cwt. per acre) are applied to stubble land the increased yield per acre from an application of 1 cwt. of sulphate of ammonia was 16·52 bushels per acre, and an increase of 30·49 bushels per acre from a 2 cwt. per acre application.

The increases in yield per acre due to the application of sulphate of ammonia applied in various quantities ranging from $\frac{1}{2}$ to 3 cwt. per acre on barley and oats for three years, 1933-35, are as follows:

Increases in Yield Due to Sulphate of Ammonia, 1933-35.

	Barley (bush. per acre).	Oats (bush. per acre).
$\frac{1}{2}$ cwt. Sulphate of Ammonia	7.42	8.04
1 cwt. Sulphate of Ammonia	16.55	16.52
2 cwt. Sulphate of Ammonia	29.06	30.49
3 cwt. Sulphate of Ammonia	34.67	36.48



Solid model showing nett profit per acre from 1 cwt. of sulphate of ammonia with oats or barley grown on stubble—Waite Institute, 1933-35—with varying prices for grain and fertilizer.

The land on which the investigations were conducted was cultivated on a wheat, oats, barley, bare fallow rotation, and each crop sown was uniformly treated with 2 cwt. superphosphate per acre. The absence of leguminous growth in the

field, and the heavy winter rainfall normally experienced at the Waite Institute, combined with the shortage of nitrate nitrogen in the soil following the removal of heavy crops of wheat, are no doubt mainly responsible for these striking responses of oats and barley to nitrogenous fertilizers.

(5) *Effect of Nitrogenous and Phosphatic Fertilizers on Wheat grown in Rotation.*

A five-year field investigation was commenced in 1929 to determine the effect of nitrogenous and phosphatic fertilizers on the yield of wheat when grown in rotation with (a) wheat, (b) barley, (c) oats, (d) peas, and (e) bare fallow. Two hundred and forty field plots each consisting of $\frac{1}{35}$ th acre in area were used for this investigation. In each alternate year one-half the plots were sown with wheat, barley, oats, peas, or left in fallow (24 plots of each treatment) without fertilizer, and the following year the block was sown entirely with wheat subjected to four fertilizer treatments, namely, no fertilizer, superphosphate, sulphate of ammonia, superphosphate and sulphate of ammonia. The results of the investigation for seasons 1931–34 are summarized on page 163. The main features of interest are the mean increases in yield over and above the no manure treatment due to phosphates, and with nitrogen and phosphate combined.

For a period of four years the mean yield of wheat without any fertilizer was as follows: Wheat after fallow, 25·44 bushels; wheat after peas, 30·73 bushels; wheat after oats, 19·45 bushels; and wheat after barley, 17·82 bushels per acre. Thus without fertilizers throughout the four-year period, the yield of wheat after peas was significantly higher than that after bare fallow, whilst both these treatments were substantially higher than wheat grown after cereals.

The increased yields per acre due to superphosphate and superphosphate and nitrogen, over and above the yields without fertilizer, are summarized below.

Mean Increases in Wheat Yield due to Phosphates and Phosphate and Nitrogen for Four Years.

Rotation.	Superphosphate (2 cwt. per acre). (bush. per acre).	Super 2 cwt. + Sulphate of Ammonia 1 cwt. (bush. per acre).
Wheat after wheat	3·19	11·37
Wheat after barley	3·14	11·36
Wheat after oats	1·93	8·75
Wheat after peas	7·44	14·88
Wheat after fallow	22·55	22·86

These results show that the response of wheat to superphosphate is very pronounced where wheat was sown on bare fallow, and over a period of four years the increased yield due to 2 cwt. superphosphate averaged no less than 22·55 bushels per acre. On the other hand, where wheat is sown after cereals the increased yield due to superphosphate is of the order of 2 to 3 bushels per acre. With wheat sown

after peas (harvested for grain) the response to phosphate is substantially better than wheat after cereals, but less than that of wheat after fallow.

When a nitrogenous dressing is added to the superphosphate there is no significant response with wheat after fallow, but a substantial and profitable response with wheat after cereals and after peas.

The results, taken in connection with other field experiments recorded in this report, show that the response of the wheat crop to soluble phosphates is dependent upon the nitrate nitrogen level of the soil. Where the nitrate nitrogen level is high, as is invariably the case with well-worked fallow, soluble phosphatic dressings can exert their maximum response. With the lower nitrate nitrogen levels, where wheat follows cereals, the response to soluble phosphates is comparatively small.

2. PASTURE INVESTIGATIONS.

From a modest beginning in 1925, the pasture investigations of the Waite Institute have gradually become sufficiently comprehensive to include the chief problems associated with practical pasture development in South Australia, and at the same time to cover a large number of basic questions fundamental to pasture research in general.

In all, 64 separate field experiments and 33 major pot culture experiments have been carried out. These have dealt in particular with factors affecting the mineral content and water requirement of pasture species, the response of pastures to fertilizer treatment, the testing of pasture species and strains, and the design of seeds mixtures, the improvement of pasture plants by selection and breeding, the question of associated growth between legumes and non-legumes, the development of pasture technique and problems associated with the management of pastures.

The active progress of the work may be attributed in large measure to the co-operative arrangement previously referred to between the Empire Marketing Board, the Carnegie Corporation of New York, the Council for Scientific and Industrial Research, and the University of Adelaide for the investigation of the mineral content of pastures. This arrangement has led to an expansion of the work in a number of directions.

The pasture investigations have also been stimulated by a growing realization in practice of the wide scope that exists for pasture improvement and the increased interest shown by agriculturalists in the establishment of seeded pastures. Furthermore, because of the complex nature of pastures and their dependence on the numerous inter-acting factors of the external and internal environment, an intelligent understanding of the phenomena involved is impossible in the absence of detailed investigation and research.

The work carried out in connection with the mineral content of pastures was described in the Report of the Waite Institute of 1925-32. More recent investigation has been essentially along the general lines laid down previously, with,

however, a greater refinement in technique, an extension of the work to cover a wider range of habitats, and a closer investigation of certain soil and climatic factors. With the gradual accumulation of data, it has become possible to classify the State of South Australia into its more important pasture zones, based on ecological desiderata relating the various types of natural and seeded pasture to the climax vegetation, soil, and climatic factors.

(1) *Top-dressing of Natural Pastures.*

Investigations which dealt entirely with natural pastures formed an important phase of the initial work on the mineral content of pastures. The first experiment, designed in 1925 to determine the effect of equivalent dressings of phosphorus (40 lb. P_2O_5 per acre) in the form of superphosphate, basic slag, rock phosphate, and the effect of nitrate of soda (78 lb. per acre) added to superphosphate, has been continued as a permanent investigation; and the effects of each fertilizer on the yield of herbage and stock-carrying capacity over eleven years are summarized on pages 168 and 169.

At the conclusion of ten seasons the relationship between the annual yield of pasture and the monthly, bi-monthly, and tri-monthly rainfall throughout the season was determined by correlation and regression. It was found that the pasture yield was largely governed by rain falling in March, April, May and June, with rains received after the end of June much less valuable by comparison; and the total yield for the season was largely pre-determined by the amount of autumn and early winter rainfall in the case of natural pastures.

Investigations were also conducted at the Waite Institute and at the Experimental Farm, Kybybolite, with a view to ascertaining the effect of phosphatic fertilizers on the carrying capacity, nutritive value, and mineral content of typical natural pastures. In these tests, Merino wethers were maintained continuously on unmanured and top-dressed pastures over a period of seasons. It was found, at each centre, that the carrying capacity of the pasture was materially increased by the application of superphosphate, but the live weight per sheep, and the quantity and quality of the wool produced by each sheep were not significantly altered.

Marked changes in chemical and botanical composition were observed as a result of top-dressing. Disabilities were evident, however, in the relatively unstable, annual type of pasture produced; and the investigations indicated that the establishment of seeded pastures, based on the utilization of superior pasture species and strains, was necessary for further improvement.

(2) *Pasture Technique.*

Much attention has necessarily been devoted to the working-out of a satisfactory technique for use in the investigation of grassland problems. Methods have been developed to measure the seasonal productivity, grazing value, and botanical composition of indigenous and seeded pastures under grazing conditions. These

are described in Bulletin 14 of the Imperial Bureau of Plant Genetics: Herbage Plants.

The sheep-shearing machine unit has been employed extensively in the harvesting of pasture samples. No other mechanical implement of defoliation has proved so effective in rapidly removing herbage to a level comparable to that remaining after the close grazing of sheep, or in following the surface irregularities of pasture land. Individual samples vary from $2\frac{1}{2} \times 5$ links to 5×10 links, and in most cases four of these samples are taken from each plot. The samples are transferred to open hessian bags and transported to the laboratories, where they are air-dried and sub-sampled for botanical analysis, chemical analysis, and dry matter determination.

The number of replications employed has varied from four to ten, and both the Latin Square and Randomized Block type of design have been used extensively. Recently, factorial arrangement of the treatments has been used to include more comprehensive systems of treatments in pasture trials. This method of experimentation has many advantages but in order to make efficient use of it, the artifice of confounding is incorporated in the design.

In regard to pot culture investigations, a high degree of uniformity and control has been attained under glasshouse conditions, and this aspect of the work has led to results which could not have been obtained with accuracy in the field. A minimum of four replications has been employed; the moisture content of the soil has been maintained by frequent weighing and watering, and mechanical losses of plant material entirely avoided.

(3) *Tests with Cultivated Pasture Plants.*

Owing to the semi-arid nature of the climatic conditions over most of the agricultural areas in South Australia, the European herbage species commonly used for grassland improvement in temperate regions have a limited application, which is confined to the exceptionally high rainfall areas and irrigated areas of the State. In order to obtain suitable pasture species for semi-arid conditions, an extensive series of tests of native and exotic herbage plants has been conducted at the Waite Institute with a view to the determination and utilization of the most satisfactory types for seeded pasture.

A grass garden was established in 1925, and in this have been grown the recognized herbage grasses and clovers, the more valuable native and naturalized pasture plants, and the more promising herbage species introduced from winter rainfall climates overseas.

Associated with the grass garden have been single plant and sward trials of the more promising species under field conditions. In the field, studies have been carried out to determine the germination and establishment, seasonal yield, persistence, drought-resistance, seed production, and general adaptability to perma-

nent grazing conditions of the more promising species and strains. Indigenous species of the *Danthonia* and *Atriplex* genera were cultivated satisfactorily, and were found to produce comparatively high yields of herbage at the Waite Institute; in this environment, however, the establishment and persistence of the indigenous species tended to be inhibited by the competitive effects of more aggressive exotic species.

The herbage plants that have proved to be of outstanding value under cultivated conditions at the Waite Institute are as follows: *Phalaris tuberosa*, Wimmera rye-grass, lucerne, and early-flowering subterranean clover. Additional species of importance under conditions of more liberal rainfall, and which are receiving detailed attention at the Waite Institute are perennial rye-grass, prairie grass, and other *Bromus* spp., and strawberry clover. Two introductions by the Division of Plant Industry of the Council for Scientific and Industrial Research, namely, *Brachypodium phoenicoides* and *Festuca Mairei*, both of which have been reported as having grown well at Canberra, are at present under test. A recent introduction from South Africa, namely *Paspalum vaginatum*, appears to be adapted to saline conditions, and is being tested for salt tolerance.

(4) *Strain Investigation of Cultivated Pasture Plants.*

(a) *Phalaris Species.*

From the inception of field experimental work with *Phalaris tuberosa*, marked variation in type has been evident among single plants of this species, and selective breeding has been carried out with the objective of producing improved pasture types. Material was obtained from natural sources in Palestine and Morocco, and in addition from California, New Zealand, and all accessible supplies in Australia.

The material from Palestine and Morocco was uniformly inferior in both type and vigour to the whole of the Australian material, and to overseas material which had in each case been obtained originally from Australia. Little or no ecotypical variation was apparent as between line and line, apart from the Mediterranean samples, but considerable variability occurred within each individual line. Single plant selection based on type, time of flowering, seed production, and vigour of development was followed by selfing to determine the degree of homozygosity for selected characters. Parent plants were then re-selected for strain-building, which is in progress.

Inter-specific hybrids between *P. tuberosa* and *P. arundinacea* have been obtained both as a result of hand-crossing and natural crossing in the field, and derivatives of this cross have also been received from Dr. T. J. Jenkin, of the Welsh Plant Breeding Station, Aberystwyth. This material is being tested under conditions of winter inundation on a heavy black soil type in the Reedy Creek area of the South-East.

(b) *Perennial Rye-grass*.

Excellent pastures of a mixture of New Zealand perennial rye-grass and subterranean clover (Mount Barker strain) have been established at Mount Barker. It is known, however, that much variation exists in the various strains of perennial rye-grass. With a view to selection, approximately 20,000 single plants of the grass derived from seed collections throughout Australia and New Zealand, and



View of selected perennial rye-grass types undergoing test prior to strain production, Waite Institute, 1936.

several European countries, were planted in the field in 1932. These plants were subjected to three heavy grazings during each growing season, and after three seasons 120 of the best plants were selected. In the autumn of 1935, these 120 plants were transferred to a new area of ground, and are being subjected to a critical yield trial of three cuts per season. Observations are being taken on the date of flowering, growth form, fertility, and rust-resistance of these plants. On the basis of the five years' data now available, line breeding will be commenced with a view to developing strains of perennial rye-grass showing superior winter growth, earliness of flowering, and rust-resistance.

(c) *Bromus Species.*

Prairie grass is a species with no well-defined rôle in South Australia, but is regarded favourably in the better rainfall or irrigated areas. Work on this species had the joint objectives of investigating the possibility of producing strains superior to commercial types, and of enquiring into the potentialities of the species as a constituent of seeded pastures. Fifty seed samples were available for the 1935 sowing. Plants of each line were included in the preliminary work at Wood's Point and at the Waite Institute. A wide range in habit was displayed by the various lines, ranging from an upright well-tillered type to a thick-stemmed, poorly-tillered but very vigorous type. Sward trials will be necessary in order to determine which type is the most productive under grazing conditions. Smut due to *Ustilago bromivora* reduces seed production in most prairie grass stands. Consequently resistance to this disease is a characteristic sought in any selected strain. Inoculation studies have indicated that resistant types do exist, but their performance under grazing has yet to be tested.

(d) *Strawberry Clover (Trifolium fragiferum).*

Strain investigation on strawberry clover commenced in 1934. Forty-eight samples, including five commercial types, were secured, and fifty plants from each line were planted out on an irrigated reclaimed swamp on the Murray River. The outstanding feature noted was the marked inferiority of the commercial lines.



Strain variation in strawberry clover (*Trifolium fragiferum*), seedling stage, Waite Institute, 1935.

They were uniformly small-leaved, short, and of low productivity. In contrast, certain of the lines directly derived from pastures were large-leaved, and produced a vigorous growth of several inches in height and of greater lateral spread than the commercial types. Single plant selections were made from the more promising lines, using productivity, freedom from virus disease, and seed production as

criteria for selection. These selections, together with new material to hand, are being used as a basis for further work. In addition a replicated sward trial has been sown in order to compare the productivity and perennality of various types under grazing conditions.

(5) *Investigations on Pasture Establishment.*

(a) *Waite Institute.*

Following the investigation of single plants and pure swards of herbage species at the Waite Institute, attempts have been made to design pasture mixtures appropriate for this and other habitats in South Australia, and to test the establishment of the mixtures under varying conditions of fertilizer and seeding treatment.

At the Waite Institute two seeds mixtures, namely (1) 5 lb. *Phalaris tuberosa* + 5 lb. early-flowering subterranean clover, and (2) 5 lb. Wimmera rye-grass + 5 lb. early-flowering subterranean clover have been developed in replicated swards and subsequently seeded over more extensive areas of cultivated land, where they are forming the subject of a grazing investigation. The establishment of *Phalaris* was found to be much reduced by the inclusion of rye-grass in the mixture, but restriction to 1 lb. Wimmera rye-grass per acre has enabled both species to establish in the same mixture, with subterranean clover. This mixture has been established over ten acres of cultivated land for an investigation of pasture management.

Lucerne has also proved a valuable pasture species at the Waite Institute. Under grazing conditions, however, the stand tends to become invaded by non-legumes of a weedy nature, and attempts have been made to incorporate sown grasses by surface harrowing into an established lucerne stand. Both Wimmera rye-grass and *Phalaris tuberosa* have been established by this means, but the establishment of the latter is uncertain, and its yield in the early phases low, when thus sown. On the other hand, lucerne-*Phalaris* mixtures have been satisfactorily established by seeding on cultivated land either in autumn or late winter.

(b) *Pasture Trials at Mount Barker.*

A comprehensive series of pasture trials has been undertaken on a typical area of land near Mount Barker. The Mount Barker district typifies an extensive area of rich land enjoying a liberal annual rainfall on which subterranean clover attains its best development.

The land in its virgin state carried a heavy timber stand, the main trees being red gum (*E. camaldulensis*) on the flats, blue gum (*E. leucoxydon*) on the better slopes, with the poorer and higher ridges carrying stringy bark (*E. obliqua*). After clearing and heavy top-dressing with superphosphate, rich pastures dominated by subterranean clover obtain. These pastures are not ideally balanced stock-food, particularly during the autumn and winter periods, resulting in diges-

tive troubles and the inefficient use of the food constituents of the pasture, particularly protein. After several years of top-dressing with phosphate, the fertility level of the land is increased materially, and the pastures become increasingly dominated by annual grass species, consisting mainly of *Bromus* species, barley grass (*Hordeum murinum*) and silver grass (*Festuca myuros*). These annual grasses are poor autumn and winter growers, and when dry, become low in nutritive value and high in fibre. The seed is inedible and is troublesome to stock, particularly sheep. The loss of weight via the "seed" is great, attaining as it does some 27–30 per cent. by weight in the case of silver grass and soft brome, and upwards of 49 per cent. by weight in barley grass. The loss of nutrients is even greater than is indicated by these figures, the "seed" being the richest part of the plant in protein, phosphorus and lime.

With a view to obtaining a better-balanced pasture, containing a higher proportion of grasses, particularly of perennial grass species, a series of trials has been laid down. In conjunction with these investigations, extensive trials have been carried out with sulphate of ammonia as a manurial dressing in conjunction with superphosphate as a possible method of increasing the carrying capacity and the milk yield from the pastures.

The first trial laid out in 1930 was designed to compare the effect of sulphate of ammonia with superphosphate on a sward dominated by subterranean clover. For the purpose, some eighteen acres of pasture were laid out in eight equal paddocks. Four of these received annual dressings of 2 cwt. per acre of superphosphate, and four received, in addition, 2 cwt. per acre of sulphate of ammonia. Two herds of milking cows were grazed rotationally on these plots for a period of three seasons, the number of days of grazing and the milk yield being recorded. The number of cows carried per acre on the superphosphate alone was an average of 0.62 per annum, whilst the plots receiving the sulphate of ammonia in addition carried 0.69 cows per acre on the average of the three seasons 1930–32. The increase due to sulphate of ammonia was therefore of the order of 11 per cent. The effect of the sulphate of ammonia on the pasture was to reduce the proportion of clover and to increase the proportion of the grass constituents, without, however, materially increasing the total yield. This feature of the effect of sulphate of ammonia was also shown in a supplementary yield test run in conjunction with the grazing experiment.

A critical comparison of the influence of sulphate of ammonia on three combinations of perennial rye-grass and subterranean clover was commenced in 1933. Pure swards of each species and a mixture of the two were sown on fallow and replicated. The whole of the swards were uniformly treated with 2 cwt. per acre of superphosphate in the autumn of each year, whilst one-half annually received additional sulphate of ammonia at the rate of 4 cwt. per acre. This quantity was applied in four separate dressings. The results show that the effect of the sulphate of ammonia on the total yield of the pasture was negligible, increasing the yield

per cut over ten cuts from 18·4 cwt. per acre to 19·4 cwt. per acre, the standard error of the increase being 0·43 cwt. per acre. Very material changes were induced in the composition of the pasture, the outstanding effect being to reduce very greatly the proportion of clover and to increase the proportion of perennial ryegrass. The yield history of the pasture is interesting, the mean yield per acre for the first year—the seeding year—being 34 cwt. of oven-dry pasture, for the second year 64 cwt. per acre, and for the third year 90 cwt. per acre. The successive large increases in yield show very clearly that pastures take several years to attain full production even though sown on fallow in fertile areas. The production of 90 cwt. per acre of oven-dry pasture is equivalent to slightly over 5 tons of pasture on an air-dry or hay basis. This compares with 140 cwt. of dry matter per acre obtained under irrigation at Wood's Point under bi-monthly cutting in 1931-32.

The search for suitable permanent grass species for the area commenced in 1929, when the eighteen acres used for the grazing trial previously referred to was surface-sown with certified New Zealand perennial ryegrass. The result was an increase of the proportion of ryegrass in the pasture from 0·4 per cent. in 1929—before sowing—to 27 per cent. on the phosphate only plots, and to 45 per cent. on the plots receiving sulphate of ammonia in addition. This increase of perennial ryegrass was accompanied by a reduction in the annual grass content of the sward from 22 per cent. in 1929 to 0·3 per cent. in 1932, the proportion of subterranean clover remaining substantially the same at 65 per cent. during this period.

In 1931 a series of plots consisting of twelve pure species and eight mixtures of these species was laid down on fallow. Of the species tried, Wimmera ryegrass, perennial ryegrass, and *Phalaris tuberosa* were the best of the grass species over a period of four seasons. No clover other than subterranean clover was found satisfactory. Following upon this exploratory trial, a more detailed investigation of the value of these three grasses when grown in conjunction with subterranean clover was commenced in 1935. The swards were sown on fallow, and are being subjected to four grazings each season, the yields being obtained by sampling prior to grazing, and botanical analyses of the herbage from each plot being made. A comparison of the rate and time of application of superphosphate is also being made in this experiment, the manurial dressings being 0, 1, 2 and 3 cwt. per acre applied in the autumn versus the same rates applied in the spring. The results indicate that both Wimmera ryegrass and perennial ryegrass are superior to *Phalaris tuberosa*, the latter being very susceptible to competition from the annual grasses normally found in the district.

(c) *Irrigated Pastures.*

Under irrigated conditions, on a reclaimed swamp at Wood's Point, near Murray Bridge, a pasture mixture of New Zealand certified perennial ryegrass 8 lb., Akaroa cocksfoot 10 lb., prairie grass 10 lb., and New Zealand white clover

2 lb., has been developed as a result of a comprehensive series of species and strain tests. This mixture has now been seeded over extensive areas of reclaimed swamp land, and has proved capable of maintaining 16 sheep per acre per annum over at least 300 acres of the mixture.

The full carrying capacity of the pasture under favourable conditions is estimated at 20 sheep per acre per annum.



View of sheep grazing on irrigated permanent pasture of perennial rye-grass, cocksfoot and white clover, Wood's Point, S.A.

(d) *Podsolized Soils.*

On podsolized soils, such as are found over extensive areas of the South-East of the State, and the Mount Lofty Ranges, it has been shown that subterranean clover must be regarded as the basis of permanent pasture development and soil improvement. The degree of production attained is largely a function of the quantity of superphosphate applied and the types of associate grasses sown in conjunction with the clover. In the absence of suitable permanent grasses, subterranean clover pastures gradually become dominated by non-leguminous species of inferior value, largely as a result of nitrogen enrichment. This phase can be to some extent avoided by the inclusion of light seedings of Wimmera rye-grass and/or *Phalaris tuberosa* with the initial seeding of clover or by seeding the pasture to these grasses after the land has grown clover for a number of seasons. Experimental work at a number of country centres has demonstrated the value of

these two grasses in conjunction with subterranean clover, and they are now being extensively used in practice. Wimmera rye-grass in particular is of immediate economic value, owing to its cheapness, facility of establishment on both ploughed and unploughed land, and the rapidity of its returns in the year of seeding. *Phalaris tuberosa*, however, although less aggressive in the early stages, is the more persistent and more stable species.

(e) *Heath Soils.*

Heath soils, of a deep sandy character, and receiving 18–20 inches of rainfall, have also been investigated from the viewpoint of pasture establishment. On these soils, deeply-rooting plants such as lucerne, *Phalaris tuberosa*, and evening



General view of experimental plots on Mallee and Heath country, Tintinara, showing pasture establishment with and without various cover crops.

primrose (*Oenothera odorata*) have proved of particular importance, and here lucerne takes the place of subterranean clover as the pioneer legume. Seeds mixtures have been designed to include lucerne and *Phalaris*, together with the ephemerals, early-flowering subterranean clover and Wimmera rye-grass, and the establishment of these species under varying cover crop treatments is under investigation at Tintinara.

(f) *Heavy Black Soils.*

Extensive areas of heavy black soils, located in the South-East of the State, provide problems in pasture establishment; and investigations are in progress in the Reedy Creek area to determine the types of pasture that can be grown and their response to phosphate. A further problem is the establishment of permanent

pasture plants under conditions of inundation by slowly-moving water in winter. It has been found that subterranean clover fails to grow normally and is, in fact, of little value on these soils.

Investigations are in progress with a view to finding suitable legumes for this soil type and determining the factors governing their development. Of the grasses, both Wimmera rye-grass and *Phalaris tuberosa* grow well on the heavy black soils, and various strains and inter-specific hybrids of *Phalaris* are being investigated under conditions of winter inundation.

(6) *Investigations on the Grazing Value of Pastures.*

(a) *The Influence of the Grazing Interval on an Irrigated Permanent Pasture.*

Investigations have been conducted at Wood's Point into the method of management of a highly productive irrigated pasture. The effects of grazing at four-weekly intervals throughout the year were compared with those of grazing every eight weeks over the summer, autumn and winter months, with the period reduced to six weeks during the spring flush. The total annual yield of dry herbage was 37 per cent. lower in the case of the shorter grazing period. Due both to the higher percentage of white clover and the less mature condition of the herbage, the mean protein content of the pasture was increased from 19·4 per cent. to 24·8 per cent. by the adoption of the shorter period of grazing. On the other hand, the total yield of both clover and protein was greater where the longer period was employed. Since the protein content under the shorter period of grazing reached the excessive figure of 31·3 per cent. during the late winter months, the longer period is preferable on grounds of both total yield and composition.

In practice, the use of short rotational periods of the order of 20 to 28 days, accompanied by drastic defoliation at each grazing, has proved less satisfactory in regard to both the pasture and the sheep than a longer grazing interval, and less severe grazing. A thirty-six day rotational period on eighteen paddocks, with a stocking rate of two to three hundred sheep per acre during the period of actual grazing, is now adopted. Modification is necessary according to season, but at all times a cover of short herbage is left at the completion of grazing. Under conditions of high temperature and low humidity, the complete or almost complete removal of green herbage by the sheep is liable to result in a severe check to the pasture.

(b) *A Comparison of Natural and Seeded Pastures, Waite Institute.*

Following the establishment of high production seeded pastures of Wimmera rye-grass and *Phalaris tuberosa*, together with early-flowering subterranean clover, investigations were commenced at the Waite Institute in July, 1935, to determine under normal grazing conditions the carrying capacity and grazing value of these pastures in comparison with top-dressed natural pasture. The latter, as a result

of previous work, had been found to carry 1.6 sheep per acre, compared with 1.0 sheep per acre on unfertilized natural pasture.

For the purpose of this investigation, two fields of 2.5 acres each were seeded with Wimmera rye-grass and subterranean clover, and two similar fields with *Phalaris tuberosa* and subterranean clover, in May, 1934; two more fields of



View of seeded pasture of *Phalaris tuberosa* and early flowering subterranean clover with quadrat removed to show growth of ungrazed herbage and sample area.

each pasture were established in May, 1935. Four further fields of top-dressed natural pasture were brought into the experiment, which thus included 5 acres of first-year seeded pasture and 5 acres of second-year seeded pasture of each type, and 10 acres of natural pasture, all of which received a similar dressing of superphosphate, namely, 2 cwt. per acre per annum. A flock of 16 Merino wethers was placed on the 10 acres of natural pasture, and a flock of 32 sheep on each of the two 10 acre areas of seeded pasture. Thus the stocking rate on the two seeded pastures was 3.2 sheep per acre as compared with 1.6 sheep per acre on the natural pasture.

As yet, the effects of the pasture on the sheep can only be discussed tentatively. The above stocking rates have been maintained, however, for a period of nearly eighteen months, and the live-weights of the sheep on both seeded pastures were superior to those on the natural pasture during the first summer and autumn, although they were better, in the case of Merino wethers, on the natural pasture in the winter and early spring. Over the period to date the greatest gains per acre have been made on the Wimmera rye-grass and subterranean clover pastures, and the lowest on the natural pastures. At the first shearing the weight of wool per head and its quality were similar on each pasture. Prior to the conclusion of seasonal growth in 1936, one-half of each field in the experiment was cut for hay, and will be fed back to the sheep on each corresponding pasture during the subsequent summer and autumn months.

(c) *A Comparison of Natural and Seeded Pastures, Kybybolite.*

An investigation similar to that described above is being carried out in co-operation with the Department of Agriculture at the Experimental Farm, Kybybolite, where the same two grasses, in conjunction with mid-season subterranean clover, are being compared with top-dressed natural pastures. In this case, however, comeback maiden ewes are being maintained on the pastures, and breeding results with these sheep are being recorded. The carrying capacity has averaged 2.8 sheep per acre on both the natural pasture and the Wimmera rye-grass pasture, whereas the *Phalaris* pasture has carried 3.0 sheep per acre. The live-weight increases at this centre, however, have been materially greater throughout the year on the two seeded pastures than on the natural pasture.

(d) *Investigations on the Management of a Seeded Pasture, Waite Institute.*

Following the design and establishment of suitable seeds mixtures and their utilization in practice, it has become evident that information is required concerning the management of these pastures in relation to the maintenance of the pastures themselves in a productive condition, and also in relation to the well-being and productiveness of the sheep. To provide for the imposition of varying forms of grazing and of pasture management on a uniform pasture mixture, an area of approximately ten acres was established at the Waite Institute in May, 1936, to a seeds mixture consisting of 1 lb. Wimmera rye-grass, 5 lb. *Phalaris tuberosa*, and 5 lb. early-flowering subterranean clover. This will be subdivided and subjected to grazing tests in 1937.

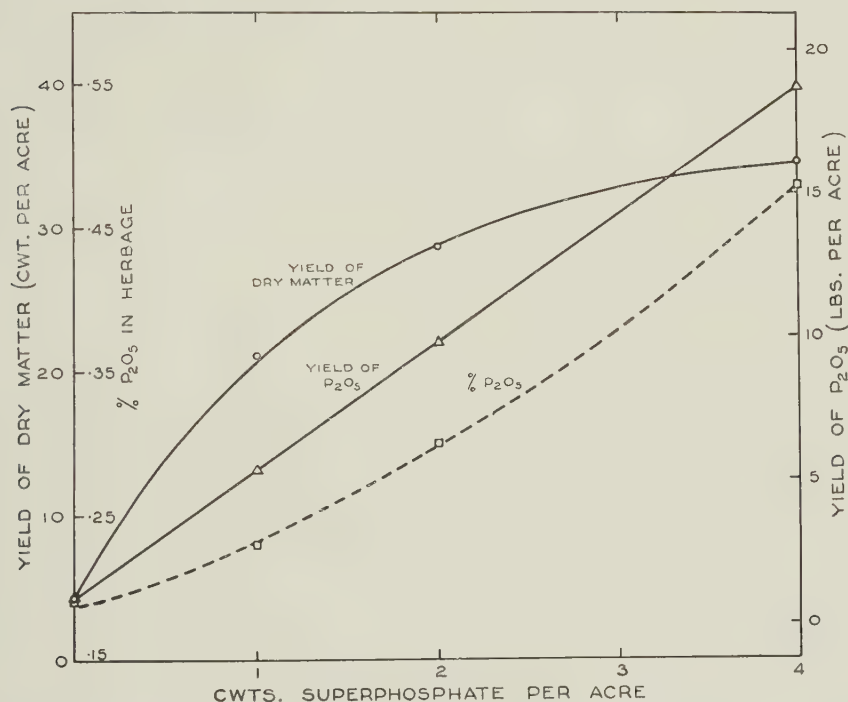
(7) *The Application of Fertilizers to Seeded Pastures.*

The problem of pasture fertilization, under South Australian conditions, has tended to be confined almost entirely to the two nutrients phosphorus and nitrogen. The fertilizers that have, in the main, been employed to make good soil deficiencies of these nutrients have been superphosphate on the one hand and sulphate of

ammonia on the other. Investigations have been carried out to determine the influence of these two fertilizers, alone and in combination, on the yield and botanical composition of seeded pasture mixtures.

(a) *The Application of Phosphate to a Virgin Podsol.*

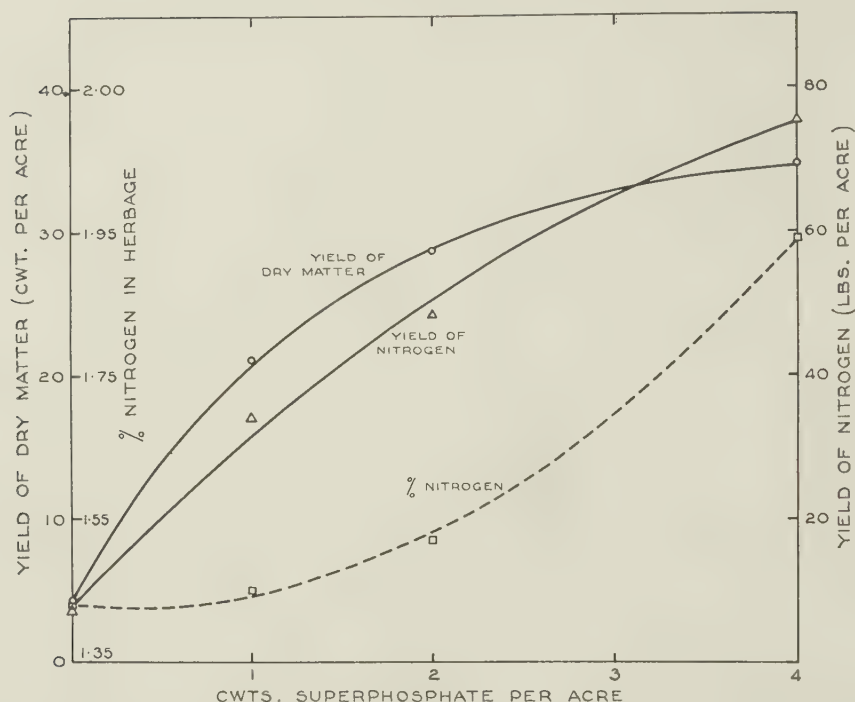
In view of the predominance of podsolized sands of extremely low natural fertility in the higher rainfall areas of South Australia and the significant rôle of soluble phosphate *cum* suitable leguminous plants in the conversion of these



Graph showing the relationship between phosphate dressing and the yield of dry matter, percentage phosphate (P_2O_5) and yield of phosphate (P_2O_5) in a subterranean clover pasture, Meadows, 1934.

soils into pastoral and agricultural assets of permanent value, an investigation was commenced on the Meadows sand type in 1934 to determine the nature of the response of subterranean clover to varying phosphate fertilization and its effect on the nitrogen enrichment of the soil.

It was found, in both the first and the second seasons, that the response of the dry matter yield to increasing applications of superphosphate tended to follow a curve of the Mitscherlich type. Tenfold replication resulted in a standard error of the mean yield for all plots of 6.86 per cent. in the first season and 3.74 per cent.



Graph showing relationship between phosphate dressing and the yield of dry matter, percentage nitrogen and yield of nitrogen in a subterranean clover pasture, Meadows 1934.

in the second season. A mean yield of 33.18 cwt. dry herbage, consisting mainly of subterranean clover, was obtained with 2 cwt. superphosphate in the first season, whereas the mean yield in the second season following 2 cwt. superphosphate in each year was 55.67 cwt. The calculated amount of available P_2O_5 in the soil per acre, on the unfertilized plots was 1.38 lb.; in the second season, following 2 cwt. superphosphate in the previous year, the amount recovered was 8.82 lb. The percentage of P_2O_5 in the herbage increased markedly with increasing phosphate application, and the percentage recovery of phosphate tended to be uniform in each of the first two seasons. The percentage of nitrogen in the herbage also increased markedly with the phosphate dressing. This was due in part to an increasing percentage of clover in the herbage, but was also due to an increasing nitrogen percentage in the clover.

(b) *The Application of Nitrogen to a Seeded Pasture Mixture under Hay and Grazing Treatment at the Waite Institute.*

The first permanent pasture mixture to be established at the Waite Institute was seeded in 1930 to a mixture of Wimmera rye-grass, certified New Zealand perennial rye-grass, *Phalaris tuberosa* and early-flowering subterranean clover.

This pasture has gradually become dominated by *Phalaris*, with smaller quantities of clover, except under continuous cutting, which has resulted in clover dominance. A basal dressing of 2 cwt. superphosphate per acre has been applied each season, and over and above this, 2 cwt. sulphate of ammonia per acre has been applied on one-half (eight) of the plots for seven seasons, whereas the remaining eight plots have received no added nitrogen over this period. The detailed results appear on pages 170 and 171.

It was found that the pasture responded slightly to nitrogen in the first season, and actively to nitrogen in the second season. Thereafter, however, the yield of the pasture was depressed by nitrogen; this effect was closely associated with the aggressiveness of perennial rye-grass, which responded strikingly to sulphate of ammonia in the second season, with resulting depression of the more permanent elements, *Phalaris tuberosa* and subterranean clover.

Associated with the above investigation were swards of pure grasses which responded actively to similar dressings of sulphate of ammonia throughout an experimental period of five seasons.

(c) *The Effect of Phosphorus and Nitrogen, alone and in combination, on the Yield and Botanical Composition of two Different Pasture Mixtures, Waite Institute.*

A further series of tests has been carried out on two pasture mixtures, one containing perennial rye-grass, *Phalaris tuberosa* and subterranean clover, the other an association of *Phalaris tuberosa* and subterranean clover without rye-grass. The results of these tests, for the three seasons 1933-35 are given on p. 172.

Nitrogen was much less effective than phosphate in increasing the total yield of seeded pasture over the second, third and fourth years of the pasture. The effect of nitrogen added to phosphate was not similar on the two types of pasture. The pasture from which perennial rye-grass was excluded responded better to sulphate of ammonia when added to phosphate than that dominated by rye-grass in the early stages. The latter behaved similarly to the mixture described in the above section (b), trending from rye-grass dominance to *Phalaris* dominance as the pasture became older, and tending progressively to yield less with dressings of sulphate of ammonia added to superphosphate than where superphosphate only was applied. On the other hand, the *Phalaris* + subterranean clover pasture produced significantly greater yields with sulphate of ammonia, and the total increase for three years, as grazed pasture, was approximately 18 per cent., compared with a slight decrease in the case of the rye-grass pasture.

(8) *Associated Growth in Pastures.*

Evidence has been obtained from three field investigations, and from eight individual experiments carried out in sand cultures, regarding the question of associated growth between grasses and legumes; and the nitrogen uptake by

grasses grown alone and in combination with various leguminous plants has been determined.

In the case of pasture mixtures containing perennial or biennial pasture legumes such as white clover, strawberry clover and red clover, grown under conditions of artificial watering in the early portion of the South Australian summer, associate grasses such as perennial or Italian rye-grass appear to be capable of absorbing small quantities of nitrogen resulting from the presence of the leguminous plants, some 12 to 16 weeks after seeding; these quantities are, however, much smaller than those suggested by various European workers. In the case of mixtures containing the annual winter-growing species, subterranean clover or the perennial species, lucerne, grown during the winter months, there has been no evidence that *Wimmera* rye-grass or *Phalaris tuberosa* is capable of deriving additional nitrogen prior to nodule breakdown, as a result of the presence of the associate legume or legumes, despite vigorous nitrogen fixation by the latter. On the other hand, in nearly all cases, the absolute quantity of nitrogen absorbed during a single growing season by grasses grown in association with legumes has been materially less than that found in the same grasses grown under similar conditions, but alone. Nitrogen becomes available from the root system of winter-growing leguminous plants as they enter the senescent condition, and in the case of associate grasses capable of extending their period of growth for several weeks beyond that of the pasture legume, material quantities of nitrogen may be gained.

(9) *The Classification and Zonation of South Australian Pastures.*

During recent years a considerable amount of information has been accumulated by various workers regarding the native climax vegetation, the distribution of the major soil types, and the various climatic relationships governing both soil and vegetation. This information has been brought together and considered in relation to the types of seeded pastures tending to be developed in South Australia in varying habitats. The concept of the length of the rain period or growing season has been developed, with particular reference to ephemeral plants; a method has also been evolved for the determination of the mean length of the rain period, as an interval of time, using the relationship between rainfall and evaporation as applied to conditions at the soil surface, under Waite Institute conditions. The factors governing the distribution of livestock, wheat and seeded permanent pasture in South Australia have been analysed, and from the data available a series of maps has been prepared from which it has been possible to indicate the location and extent of the main zones of pasture development in South Australia.

(10) *The Study of a Typical Mitchell Grass Pasture from Queensland.*

In co-operation with the Research Department of the Australian Estates Co. Ltd., a detailed study of the yield, botanical and chemical composition of a typical Mitchell grass pasture is being conducted for a period of twelve months.

An area of Mitchell grass pasture at the Company's Elderslie Station, Winton, Queensland, has been selected by Mr. J. F. Kennedy, B.Ag.Sc., who has made the pasture cuts and forwarded the samples to the Waite Institute. The object of this trial is to ascertain the rate of growth and the nutritive value of a pasture from a summer rainfall area of Australia, with a view to defining the onset and duration of the period of nutritional stress to which the grazing stock are subjected, and to explore the possibility of fodder conservation in good seasons from Mitchell grass pastures to provide some measure of insurance against periodic drought.

Commencing in September, 1935, pasture cuts were made on grazed and ungrazed pasture at 28-day intervals throughout a period of 12 months. The samples thus obtained are air-dried at Elderslie, shipped to the Waite Institute, where the botanical separation and chemical analyses are being made and the weights recorded.

3. PLANT BREEDING AND GENETICS.

Recent developments in the wheat situation indicate that growers are emerging from one of the most difficult periods in the history of the industry. This period of unprofitably low prices has emphasized the fact that increased returns to the grower at no additional cost are available by growing varieties of improved yielding ability, of desirable agronomic characters and adapted to the climate and soil type of a district.

The wheat breeding programme of the Waite Institute entails the production of varieties which are superior to existing varieties in yielding ability and resistance to disease, with grain characters which will fulfil the requirements of our export trade in wheat and the requirements of millers and bakers for the local and export trade in flour.

New and improved varieties of wheat produced at the Waite Institute are now under test both in experimental plots at Glen Osmond and on farms at Yurgo, Tarlee, Pinnaroo, Alma and Yeelanna.

The results of yield trials with new varieties tested in replicated plots at the Waite Institute during the years 1933-1935 are presented in the appendix tables of this report.

New strains of high yielding ability and possessing desirable agronomic characters are Sepoy Selection, Gluyas x Minister, Federation x Minister, Ford x Hard Federation, and Gluyas x Unknown.

Disease Resistance.

Natural infection with the two rusts, stem rust (*Puccinia graminis tritici*) and leaf rust (*Puccinia triticina*), occurs in the breeding plots at the Waite Institute every year, and usually to a sufficient degree to make selection for resistance possible. Efforts have therefore been concentrated on the production of varieties

resistant to rust. The first cross, made with this objective in 1928, was between Hope, which is resistant to bunt, loose smut, flag smut and rust, and Gluyas. Since 1928 other immune varieties have been used as parents, and by the use of all available methods such as back crossing to one parent, composite crossing, the bulk population methods and pedigree selection, some 796 rust-resistant strains, in the



New crossbred wheats undergoing tests for yield, Waite Institute, 1936.

fourth to the eighth generation, are available for selection for yielding ability. Four strains from the original Gluyas x Hope cross have reached the drill plot test, and 34 strains are now under test in replicated rod-rows.

Yield tests of rust-resistant strains in replicated rod-rows in 1935 gave the following results:

Pedigree number.	Cross.	Mean yield bush. p. ac.	Days to heading.	Pelshenke time value.	Leaf rust 0 — 5	Stem rust 0 — 5
7067	Gluyas x Hope	28.7	100	160	0	0
7179	Gluyas x Hope	33.0	102	81	1	1
7181	Gluyas x Hope	32.1	101	86	1	1
7182	Gluyas x Hope	33.9	102	54	2	0
7183	Gluyas x Hope	34.9	100	36	4	1
7184	Gluyas x Hope	29.8	103	105	0	1
Check	Nabawa	32.1	100	32	5	5

Rust resistance in the variety Hope behaves as a dominant character and therefore the backcross method of breeding can be employed with advantage. The first back crosses, e.g. Nabawa x (Nabawa x Hope) were made in 1930 and since then this method and also the method of composite crossing have been employed extensively, as indicated in the following examples: [(Dundee x Ford) x (Gluyas x Hope)] x [Nabawa x (Sepoy x Hope)], and [(Kenya Crossbred x Ghurka) x (Gluyas x Hope)] x Ghurka.

The Hope crosses have also provided material for selection for resistance to other diseases. Inoculation of rust-resistant strains with loose smut and bunt has isolated strains which are resistant to one or both of these diseases. Strain 7067 in the above table is resistant to both loose smut and bunt.

Baking Quality.

At the initiation of the wheat breeding programme in 1928, varieties of good baking quality, such as Minister, Hard Federation, Florence, Hope and Pusa 4, were crossed with the three popular varieties—Gluyas, Nabawa and Ford, with the object of combining yielding ability and a reasonably good baking quality in one or more varieties.

Selections derived from a number of these crosses are of high yielding ability and satisfactory baking quality as judged by a baking test conducted on grain samples from the 1935 harvest. The following table presents a summary of baking tests and yield in replicated plots of five new strains. The Waite Institute is indebted to the State Department of Chemistry for the baking test results. In this table strains numbered 1, 2 and 3 were sown in June, and the remainder were sown in July, 1935.

Baking Tests and Yields of five new strains of Wheat in comparison with Nabawa.

Test Number.	Strain.	Maltose %.	Protein %.	Water Absorption.	Standard Test.			Baking Score	Bushel Weight, lb.	Yield % Nabawa.
					Loaf Wt.	Loaf Vol.	+ 0.5% Malt. Loaf Vol.			
1	Nabawa	1.75	7.99	51.7	128.4	315	320	31	63.6	100
2	Sepoy Selection	1.39	7.42	52.8	127.5	425	450	37	63.4	143
3	Federation x Minister	1.82	7.16	53.6	130.0	410	410	38	64.5	132
4	Nabawa	1.62	9.50	51.5	126.2	375	405	38	61.1	100
6	Ford x Hard Federation	2.37	9.99	53.6	128.2	365	370	39	63.3	106
9	Sepoy x Federation	1.00	10.05	49.7	124.1	430	470	42	61.5	110
10	Nabawa x Hard Federation	1.41	9.26	51.8	124.4	450	465	43	61.8	96

Barley.

The development of a smooth-awned feed barley from a cross between the variety Cape and a smooth-awned Canadian barley is in progress. A total of 105 fourth generation rows is under test this season.

Field Peas.

Three strains of field peas derived from the crosses White Arir x White Brunswick, Lemaire x White Brunswick, and Crossbred D x White Brunswick are sown in field plots. The strain White Arir x White Brunswick is earlier than the White Brunswick parent.

A bulk population consisting originally of the F_2 generations of approximately 20 crosses is being continued from year to year. At the end of five years single plant selections will be made from this material.

Plant Genetics.

A. Inheritance of new characters in Wheat.

1. A third gene for awnedness has been isolated which, unlike the two known genes, is completely awnless in the homozygous condition, while the heterozygote is almost completely awned.
2. The inheritance of hairs on the auricles of the wheat plant is dependent upon the operation of duplicate genes.
3. Variegated wheat, characterized by longitudinal yellow or white stripes on the leaves and stems is inherited through the female parent only.

B. Studies on inheritance in speltoid mutants is being continued.

C. Interspecific and intergeneric hybrids.

1. Inheritance in interspecific crosses with wheat in relation to speltoid types is almost completed.
2. The production of intergeneric hybrids between *Triticum*, *Agropyron* and *Lolium*, and a study of the relationship between the genera is in progress.

4. PLANT PHYSIOLOGY.

(1) *Growth Studies.*

The growth and development of the plant are the result of a large number of metabolic reactions proceeding within its cells during the life-cycle. These reactions are integrated in such a way that various attributes of the plant undergo characteristic drifts with time. The drifts typify the developmental history or ontogeny of the plant; they are seen in its size, structure, and chemical composition, and in the rate of change of these attributes, and also in the actual rates of the metabolic reactions themselves.

The ultimate understanding of growth necessitates an understanding of the nature of the integration of ontogenetic processes. Much work will be required to achieve this; but the first task is clearly the intensive study of ontogenetic drifts of various kinds and the search for inter-relations among them. This study has been in progress for several years in the Department of Plant Physiology. Its subject is one of considerable value in agriculture: here the growth of the plant, and the changes in composition and in relative proportions of the parts of the plant, and the factors governing these changes, are of great practical importance.

Some of the initial stages of the study were described in the previous Waite Institute Report (pp. 45-48). It was shown how the potassium and calcium contents of the plant underwent drifts that are characteristic features of ontogeny. It was also shown how these drifts appear to be related to the as yet incompletely explained drift in the water content of the plant and to the respiration rate: in this way some insight was gained into the integration of certain ontogenetic drifts.

Now it is known that the chemical composition of the plant not only drifts with time but varies with the nutrient supply. It has therefore been considered that the observation of ontogenetic drifts under different initial supplies of nutrients should be a valuable method of approach to the present subject of study. This consideration has led to the investigations on the relation of nitrogen and phosphorus supply to growth also referred to in the previous Report.

The first phase of these investigations has concerned the drifting growth rate. As a measure of this is taken the rate of increase per unit of dry weight, or relative growth rate, given by R in the equation

$$R = \frac{1}{W} \frac{dW}{dt},$$

where W is the dry weight of the plant and t the time. This can be resolved into two factors, namely the fraction of the plant that is producing new dry matter, and the rate of production by this fraction.

The new dry matter is produced mainly by the leaves, and consequently the first factor is known as the leaf weight ratio, F , given by

$$F = W_L/W,$$

where W_L is the dry weight of the leaves.

The second factor is the rate of increase in dry weight of the plant per unit of leaf, and is known as the unit leaf rate, E , given by

$$E = \frac{1}{W_L} \frac{dW}{dt}.$$

The effects of different initial supplies of nitrogen and phosphorus on these quantities in gramineous plants are illustrated in the accompanying graphs.

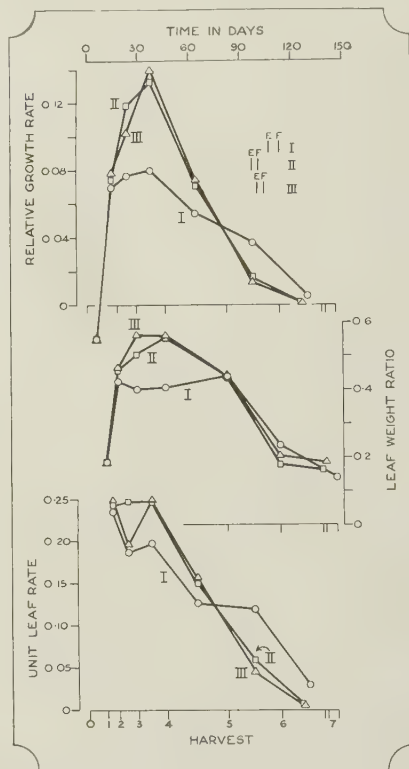
In the previous Report it was shown that an increasing supply of nitrogen causes at first a depression in the dry weights of the whole plant and its parts; later this depression passes off and, provided the supply does not exceed a certain

limit, gives place to an increase with treatment. We now see from the first graph that, in the early stages of growth, the relative growth rate is less, the greater the nitrogen supply. After the maximum is attained, however, the rate becomes greater with higher treatment. The reduction in relative growth rate with treatment in the early stages may be produced by effects on both leaf weight ratio and



Curves of relative growth rate (gm. per gm. per day), leaf weight ratio and unit leaf rate (gm. per gm. per day) in Sudan grass with three nitrogen treatments I, II and III.

E indicates time of exsertion of inflorescences, and F time of flowering.



Curves of relative growth rate (gm. per gm. per day), leaf weight ratio and unit leaf rate (gm. per gm. per day) in oats with three phosphorus treatments I, II and III.

E indicates time of exsertion of inflorescences, and F time of flowering.

unit leaf rate, although the depressions in these quantities shown in the first graph are not statistically significant. After the maximum is attained, the effects on relative growth rate are mainly attributable to the effects on the leaf weight ratio. After the exsertion of inflorescences, however, the high value of the relative growth rate with treatment III is contributed to by the significantly greater value of the unit leaf rate with this treatment. In another experiment with wheat, the unit leaf rate was found to have an effect over a longer period.

Phosphorus experiments show that with increasing supply there is an increasing production of dry matter up to a certain point, after which further increase in supply results merely in a depression in dry weight during the early stages of growth. In the second graph it is seen that the relative growth rate, unit leaf rate, and leaf weight ratio are comparatively low with low phosphorus supply. Later the values of these quantities with this treatment become the highest, but in senescence they tend to converge on those obtained with the other treatments. In early adolescence the relative growth rate and unit leaf rate are slightly depressed, and the leaf weight ratio is increased, with the highest phosphorus supply. For the rest of the growing period the values of all three quantities are insignificantly different with the two highest phosphorus supplies.

Marked differences in the effect of increasing the supply of nitrogen and phosphorus are apparent in the graphs, but there is, nevertheless, no reason to believe that these two nutrients have specific effects on the rate of dry matter production. The apparent differences are probably attributable to the relative proportions in which the two elements are present in the nutrient medium. The plants receiving the two high phosphorus treatments were limited in growth by the amount of nitrogen supplied, whereas it is improbable that any of the plants in the nitrogen experiment were appreciably limited by any essential element other than nitrogen. This difference probably accounts for many of the differences between the results of the two experiments, especially during the later stages of growth. Moreover, increasing nitrogen supply is generally found to delay senescence, whereas increasing phosphorus supply hastens it; certain data, however, suggest that, when nitrogen supply is not limiting, senescence is delayed by increasing phosphorus supply. In practice, gramineous plants are generally grown under conditions in which nitrogen supply limits the vegetative growth, so that the effects obtained by increasing phosphorus supply generally agree with those found in these investigations.

Studies now in progress aim at relating the effects of the supply of nitrogen and phosphorus on the relative growth rate and its factors to effects on the chemical composition of the plant, especially in regard to proteins and complex phosphorus compounds.

(2) *Studies in Nitrogen Metabolism.*

These growth studies have revealed a number of problems that require a more intensive approach than that described in the foregoing paragraphs. Such problems appear especially in connection with the correlation of ontogenetic drifts in the contents of nitrogen compounds and other constituents of the plant. Furthermore, one particular group of nitrogen compounds, the proteins, are of great importance in metabolism, and it is largely due to its effect on the amount of protein nitrogen in the plant that the supply of nitrogen affects growth. The factors determining the proportion of nitrogen compounds in the plant at various growth stages are thus important.

For the investigation of the problems arising from these considerations, a new technique has been developed in collaboration with Professor J. G. Wood, of the University of Adelaide. In the case of carbon metabolism, it is easy to measure momentary rates of metabolism by gas analysis methods, but such measurements are impracticable in the case of nitrogen metabolism. The method adopted has therefore consisted in placing plants, submitted to different treatments, in an environment constant in regard to a number of its properties. In this way it has been possible to determine the amounts of various components of the plant when an equilibrium state has been attained.

Statistical examination of the data obtained in this manner shows that, when phosphorus is present in excess, apart from a small effect of the pH of the expressed sap, the protein content of the leaves of grasses is almost completely accounted for in terms of the amino-acid content and the water content. Protein-nitrogen content can be expressed as an increasing function of each of these variables. It follows that reduction in water content causes protein hydrolysis. If it is assumed that there is a reversible equilibrium between proteins and amino-acids, then it might be concluded that reduction in water-content caused a change in the velocity constants of either the forward or backward reactions. This conclusion is, however, unnecessary, as the data can be explained on the assumption that the curve relating the equilibrium concentration of proteins and amino-acids is concave to the amino-acid axis. Investigation of the relationships among other nitrogen compounds is proceeding.

These investigations have not only enlarged our knowledge of nitrogen metabolism but are also proving of value in the interpretation of nutritional relationships and growth. This especially applies to the discovery of the intimate relation between protein and water contents; the protein content being a major factor determining metabolic activity, a key is provided to the effects of variation in water content on the plant.

(3) *Relation of Transpiration Ratio to Nutrient Supply.*

It is well-known that the transpiration ratio, or ratio of the amount of water transpired by a plant in a given time to the amount of dry matter formed during that time, is reduced by increase in the supply of certain nutrients. The growth studies on gramineous plants have incidentally provided data which have rendered possible an analysis of this phenomenon.

In the previous Report it was stated that, in the case of increasing nitrogen supply, there is no significant effect on the transpiration rate per unit of leaf; but that the leaf weight ratio increases with nitrogen supply throughout most of the growing period, so that the rate of transpiration per unit weight of whole plant actually increases with treatment. In this way, increasing nitrogen supply tends to increase the transpiration ratio.

This tendency to increase the ratio is more than counter-balanced by an effect of increasing supply on growth. At any point prior to that of harvest, the ratio

of the amount of dry matter produced after that point to the amount produced before it, is greater the greater the nitrogen supply. It follows mathematically from this that increasing supply reduces the transpiration ratio.

In the case of phosphorus supply the mechanism of the reduction in transpiration ratio presents marked contrasts to that in the case of nitrogen. The transpiration rate per unit weight of leaf is decreased by increasing supply and, as the leaf weight ratio is in this case reduced during part of the growing period (second graph), the transpiration rate per unit of plant is reduced considerably.

The growth effect produced by increasing phosphorus supply is the reverse of that produced by increasing nitrogen supply. At any point prior to that of harvest, the ratio of the amount of dry matter produced after that point to the amount produced before it, is generally less the greater the supply. This tends to increase the transpiration ratio, but the tendency is more than counter-balanced by the decrease produced by the rate factor.

(4) *Physiological Studies on the Tobacco Plant.*

The growth studies on gramineous plants described in section (1) have recently been extended to embrace investigations on the tobacco plant. This work is being carried out on behalf of the Council for Scientific and Industrial Research. Professor J. C. Earl, of the University of Sydney, has shown that bad quality in certain Australian tobacco is associated with a comparatively low ratio of organic acids to nitrogen in the leaf. The present investigations aim at elucidating the factors that determine the relative amounts of these two constituents of the leaf at the time of picking. The work on gramineous plants has shown that the nitrogen content of the plant can be decreased by increasing phosphorus supply, and an experiment in progress is devoted to an examination of whether this holds also for the tobacco plant, and of how phosphorus supply effects the organic acid content of the leaves. At the same time, a fundamental study is being made of a number of aspects of the physiological ontogeny of the tobacco plant, as it is felt that this will be a valuable foundation for any future work on the physiological factors that determine quality in the cured leaf.

5. BOTANY.

Most agricultural problems have a botanical side; investigation, even of the most specific of them, usually calls for decisions on questions of either plant morphology or plant physiology, or of both. The results achieved by such investigation, aside from their practical significance, sometimes include contributions of material value to botanical knowledge. For example, in the course of research work conducted at the Waite Institute with a view to pasture improvement, there has been developed a technique whereby it is now possible to identify the more important species of grasses, clovers, and other legumes, from their vegetative

characters alone and in their very early stages of growth. This, in itself, represents a contribution to our knowledge of plant morphology; and it further offers a starting point for additional research of a similar kind, and for which the need is becoming every day more apparent in view of the importance of prompt identification in certain cases in which the material submitted may, for various reasons, be imperfect and fragmentary. Under South Australian conditions, for example, the majority of plants flower towards the latter end of the year; on the other hand, mortalities among stock, associated with the ingestion of plants poisonous or otherwise harmful, mostly occur during the first six months of the year. The futility, in such circumstances, of being obliged to wait for perhaps three months in order to obtain flowers of a suspected plant for purposes of identification, is quite obvious.

But, apart from such botanical research as is inseparable from the investigation of problems of direct agricultural significance, a good deal of work of a general nature is being carried out. This is exclusive also of that incidental to the care and maintenance of the Herbarium of dried plants, and the field Arboretum of trees and shrubs. Additional to the above there are two phases of work which, though interrelated, may conveniently be considered under the following headings:

Educational: The disbursement of information in response to enquiries received, both directly and indirectly, through the Department of Agriculture, occupies a considerable amount of time, but, notwithstanding the limitation it imposes upon the time available for experimental work, it is felt that this work is sufficiently important to deserve far more than casual attention. Not only does it represent a service to the community at large, but also it is a means whereby the Waite Institute is kept in direct touch with problems confronting individual farmers, pastoralists and others. It is realized that the number of problems that, at any one time, can be the subject of active research is small in comparison with the number deserving attention. Simultaneously, therefore, with the progress of experimental research it is an important phase of work to make available to the farming community, not only the results of such research, but information on a much wider range of subjects as well, in response to enquiries received.

Many such enquiries are of a botanical nature, and these include the submission of plant specimens for identification and report, requests for information as to the properties, poisonous or otherwise, of native and introduced species, the fodder values of various plants, their potentialities as noxious weeds, ways and means of eradicating them, etc. During the period from April to November of this year (1936) upwards of one hundred and sixty plant specimens were received from outside sources for identification and report, and among these were two (perhaps three) species new to South Australia, as well as a number of new localities of plants previously recorded from other parts of the State. In addition to these about forty other plants were reported upon, and detailed instructions were given in response to some thirteen enquiries relating to the eradication of specified noxious weeds.

During May of this year articles, descriptive of some important weeds of South Australia and previously published in the Journal of Agriculture, S.A., were partially revised and supplemented with additional photographs prior to their reappearance as a bulletin which has since been issued by the Department of Agriculture. This series of articles is being continued.

Investigational: The work comprised under this heading has been partly observational and partly experimental. As regards the first, the main item has been a search for plants of potential value as sand-binders, or drought-resistant fodders, as a preliminary to mapping out a programme of work in connection with soil erosion problems. An effort is being made to obtain seed of as wide a range as possible of suitable species with a view to testing them experimentally under field conditions. To enable a start to be made during the coming year two excursions have recently been made into dry country districts for the purpose of obtaining the necessary supply of seed. In the short time available it has not been possible to make an exhaustive search, nor has seed been obtainable of all species of probable value. It is recognized that the collection of seed will require to be continued throughout the greater part of next year, and that a much larger area will need to be traversed in order to obtain the necessary range and quantity of suitable species and strains. Nevertheless, seeds of approximately one hundred different species have been collected to date, including various grasses, such as species of *Stipa*, *Triodia*, *Danthonia*, *Schismus*, etc., saltbushes, bluebushes, and their allies, namely, species of *Atriplex*, *Rhagodia*, *Kochia*, and *Bassia*, squash-bushes, *Zygophyllum* spp., nitre-bush, *Nitraria* sp., and a miscellaneous assortment of other herbs, shrubs, and even trees.

As regards experimental work, early in the year the Wallaroo-Mount Lyell Fertilisers Limited kindly presented the Waite Institute with a quantity of sulphuric acid for weed-spraying purposes. During July, an area badly infested with charlock (*Brassica Sinapistrum*, Boiss.), and situated in an oat crop grown on stubble at the Northfield Mental Hospital farm, was sprayed with the acid. The area was divided into thirty plots, with six replications of each of five treatments, viz.: unsprayed, sprayed with 5 per cent., 10 per cent., 15 per cent., and 20 per cent. respectively, of the pure acid (by weight). A detailed examination of the comparative results of the different treatments has not yet been made, but from inspection of the area as a whole the following results are apparent:

- (1) Outside the sprayed area competition of the oat plants appears to have been sufficient to overcome nearly all weeds except the charlock.
- (2) The area selected at the time for spraying was much more densely infested with this weed than areas adjacent to it.
- (3) Very few charlock plants are now to be seen on sprayed plots.
- (4) Parts of the crop adjacent to this area are now badly infested with charlock.
- (5) No signs of injury to the crop plants were noticed on the area sprayed with sulphuric acid at all concentrations.

Agricultural Chemistry and Bacteriology

1. SOIL INVESTIGATIONS.*

One of the principal objectives of the Division of Soils of the Council for Scientific and Industrial Research is the carrying-out of systematic soil surveys. The large area of Australia in relation to the human resources precludes any attempt at detailed work over any considerable extent of country, so that attention has been directed on the one hand towards an understanding of the distribution of the principal soil zones, and on the other hand to the survey of those areas which present special problems, or where the intensity of settlement is such as to justify detailed work as in the irrigation areas in the valleys of the Murray and of the Murrumbidgee.

Reports dealing with some of the areas mentioned in the previous report have been published subsequent to that report, and these areas include Gingin in Western Australia, the apple-growing districts of Tasmania, and the irrigation areas in the neighbourhood of Berri and of Barmera in South Australia.

Since 1933 most of the surveys have been concentrated in the irrigation settlements of New South Wales. These occur in two groups, one near Wentworth, and the Mirrool and Yanco areas included in the Murrumbidgee schemes.

The field and laboratory investigations relating to these surveys have now been completed, and form the subject of bulletins in press or accepted for publication. With the completion of work in New South Wales, activities have been transferred to the irrigated areas in the Mildura district where, in co-operation with the Department of Agriculture of Victoria, surveys similar to the above are being undertaken.

In Tasmania the work of the Division is carried out from the University of Hobart, and the principal area investigated has been the north-west coast, where the basaltic red soils are an important factor in agricultural development.

A survey of the group settlements near Denmark in Western Australia has also been completed, but the records await co-ordination before publication will be possible. In this particular case the work is the result of co-operation between the Division of Soils and the Department of Agriculture of Western Australia. The soils are associated with a wasting disease of dairy cattle, which has been shown by the State Department to be due to a deficiency of cobalt and possibly of other metals. There is considerable evidence that the south-west corner of Australia is likely to be found to be deficient in these metals required in traces by plants and animals.

The completion of the surveys of all the most important horticultural areas is now in sight, and before long it will be necessary to give a new orientation to the

* For papers dealing with this section *vide* Publications 1-21.

work. Already the surveys are being made use of in the study of irrigation and drainage requirements of the various soil types encountered, these further studies being in the hands of officers of the Council stationed at the research stations at Merbein and Griffith.

More general descriptions of soils based in the main on laboratory studies have been the subject of other publications. These deal with a comparison of the black soils of eastern Australia with the black cotton soils (regur) of India, and with an account of some of the properties of a group of basaltic red soils from Queensland and New South Wales. Work on a range of samples from the red-brown earth zone of South Australia is in progress.

The ratio between the carbon and nitrogen content of Australian soils has been examined for a large number of samples covering most of the soil zones. The ratios are found to fall into two groups determined primarily by the associated vegetation, the grasslands and the woodlands.

The general principles of soil classification and of nomenclature have been further studied; the correlations between mechanical analyses and field estimates of texture have been the subject of a report to the International Society of Soil Science. These correlations are not, however, universal in their application, and it has been found that soils of the Murrumbidgee Irrigation Areas do not conform in this respect to standards established for the Murray Valley. These differences form the subject of further study in the laboratory. Further correlations with the standards established in the United States are being sought, and an officer of the Division has been sent to the University of California for this purpose.

The subject of soil colour is also being examined. Colour is an important field criterion in survey work, and in some cases, as in the basaltic areas of north-west Tasmania, may be the most important characteristic on which differences may be established. The main contributing factors to colour are the content in humus and in oxides of iron, but the relationships are not entirely simple.

Methods for the examination of soils have been further developed, and have included studies of lime requirements with special reference to Tasmanian soils. A related determination, that of exchangeable hydrogen, has also been found capable of simple estimation. The cobaltinitrite method for the determination of potassium has been investigated, and the conditions under which it can be used for soil extracts have been determined.

Methods for the determination of carbon and nitrogen were also examined in association with the Rothamsted Experimental Station.

The importance of minor elements in animal and plant nutrition is becoming increasingly important, and methods for the reasonably accurate determination of elements present in the soil in traces have been studied. Chemical methods are being examined at the Waite Institute, and spectrographic methods at the University of Melbourne.

2. MANGANESE DEFICIENCY.

Since the account of this problem was published in the 1925-32 Report little further experimental work has been carried out at the Waite Institute, interest having been mainly centred on the practical application of the results of the earlier work.

Production of Manganese Sulphate in South Australia.

At the commencement of this investigation manganese sulphate was available only as the commercial chemical, the price of which (£150 per ton) was prohibitive except for the early experimental work. When its value as a fertilizer was demonstrated local companies imported supplies from America at £30-£35 per ton. Since large supplies of precipitated manganese dioxide were available in Australia as a by-product from the electrolytic refining of zinc, the possibility of the local manufacture of manganese sulphate was pointed out, and the process has now been developed successfully by the various fertilizer companies, enabling manganese sulphate to be marketed at £15 10s. per ton. The locally manufactured product is largely sold as a mixture with superphosphate, each bag containing 159 lb. of superphosphate and 28 lb. of manganese sulphate.

The consumption of this mixed fertilizer has shown a steady increase in South Australia, the output for the three years 1934, 1935 and 1936 being 290, 388, and 481 tons respectively. It is estimated that the latter amount would be sufficient for 8,000-10,000 acres at the average rate of application. During 1936, 86 per cent. of the total output was supplied to the southern portion of Yorke Peninsula. Owing to the prevalence of manganese deficiency in this area it has now become the general practice of a number of farmers to use the superphosphate and manganese fertilizer. In contrast to this, only 3 per cent. of the output is used in the South-East of South Australia—the district in which manganese deficiency was first identified and its control demonstrated.

Field Experiments.

The Department of Agriculture has continued the field experiments on the response of barley to manganese sulphate, started at Corny Point in 1928, and the following table covering the results for the last four seasons has been compiled by courtesy of Mr. R. C. Scott, Chief Agricultural Instructor.

*Average Yield of Barley following Applications of Manganese Sulphate,
Corny Point, 1931-35.*

Amount of Manganese Sulphate.	Yield.
Nil.	16 bush., 21 lb.
14 lb.	23 bush., 49 lb.
28 lb.	26 bush., 45 lb.
42 lb.	27 bush., 44 lb.

All plots received a basal dressing of 1 cwt. superphosphate. Over a series of years now these plots have shown a most striking response to manganese sulphate, as little as 14 lb. per acre showing nearly 50 per cent. increase in yield. It would appear that the most profitable dressing of manganese sulphate at this locality is between 28 and 42 lb. per acre.

Availability of Manganese in the Soil.

The views expressed previously that the oxidized forms of manganese ("manganese dioxide") were unavailable to plants and only became available on reduction to manganous ions, have been modified somewhat in the light of the more recent experimental work of Mr. G. W. Leeper at the University of Melbourne. Leeper* has divided the manganese of the soil into four groups (excluding manganese present in unweathered minerals):

- (a) Exchangeable manganese;
- (b) Reactive manganic oxide;
- (c) Slightly reactive manganic oxide;
- (d) Inert manganic oxide.

Exchangeable manganese only occurs in significant amounts in acid soils since it is readily converted to reactive manganic oxide under alkaline conditions. It is now considered that both forms together constitute available manganese, although the former is much more readily available than the latter. Thus if an acid soil, normally containing just sufficient exchangeable manganese to support healthy plant growth, is heavily limed, manganese deficiency is likely to appear owing to the reduced availability of the manganese now occurring as reactive manganic oxide.

Leeper has developed a chemical method which enables the amount of exchangeable manganese and reactive manganic oxide to be determined, either separately or together, by leaching the soil successively with a normal solution of ammonium acetate, adjusted to pH 7, and the same solution containing 0.2 per cent hydroquinone. By means of this test he has successfully predicted that certain acid podsols would show manganese deficiency if heavily limed. The Victorian examples of manganese deficiency are all of this type, produced by liming, whereas the South Australian occurrences are on soils naturally neutral or alkaline. If a soil yields less than about 25–50 parts of available manganese per million parts of soil by Leeper's test, and is neutral or alkaline in reaction, then it is probable that plants growing on that soil will suffer from manganese deficiency. The method furnishes a simple test which should prove of considerable value in advising on the use of manganese fertilizers.

* Leeper, G. W.: Proc. Roy. Soc. Vic., 47: 225, 1934.

3. THE CHEMISTRY OF PASTURES.

The study of the chemical composition of pastures is complementary to the agronomic studies of cultural methods, fertilizers and the introduction of new species and strains of fodder plants. The influence of these factors on the composition of pure species and of pastures has been studied both in pot culture experiments and in field plots.

The comparative poverty of the soils of this State in available phosphorus has led to the investigation of the response of natural pasture to superphosphate. The striking effects on the chemical composition were the result of two influences, an alteration in the composition of the individual species and a change in the proportion of these species in the sward. Similar effects were found both at the Waite Institute and at the Kybybolite Experimental Farm, although to a much greater degree in the latter case. Here was found to occur a cycle in the nitrogen, phosphorus and calcium content of the herbage which was correlated with an alternate increase and decrease in the leguminous element of the sward. Encouraged by the phosphate dressing the legumes first assumed a position of dominance, until a sufficiently high nitrogen level in the soil had been attained to provide a favourable environment for the rapid development of the grasses.

Whether fertilized or not, the nutritive value of the pasture shows a seasonal trend attaining a peak value in September and falling steadily thereafter until maturity is reached. From this point there sets in a progressive impoverishment as the result of loss of leaf due to selective grazing and climatic influences, and the falling of the seed in which may be concentrated as much as 60 per cent. of the total phosphorus and protein elaborated by the plant. In late autumn therefore, the herbage although not lacking in quantity deteriorates to such an extent as to give a net energy value of 16.6 cals. per 100 lb. as against a spring value of 60 cals. per 100 lb. and to approximate in composition to wheat straw. This depreciation is reflected not only in the marked decline in the body weight of the sheep but in a pronounced "break" in the wool.

This loss in nutritive value of such pastures is accentuated by the encouragement through top-dressing of the short-lived free-seeding annual plants. Pastures of perennial species, on the other hand, by their stability, more extended growing period, response to fertilizers, and ability effectively to utilize summer and autumn rainfall offer distinct advantages over the natural pastures provided, that the nutritive value can be shown to be satisfactory. Investigations into the chemical composition of such perennial pastures are proceeding. A pre-requisite to the study of these problems however, is a knowledge of the degree of accuracy of individual values obtained for the percentages of chemical constituents in the herbage under the various treatments. This chemical problem has never been the subject of critical investigation. Accordingly a plot of sown pasture $\frac{1}{20}$ th acre in area has been divided into 400 plots. The herbage from each has been harvested

separately, dried, weighed, and the nitrogen determined. In order to test the variability in botanical composition a block of 120 samples was hand-separated into legumes, grasses, and miscellaneous plants, and the contribution of each to the total yield determined. A statistical examination of the data will show not only the variability of the pasture both in yield and chemical composition, but will indicate the size and shape of plot and the number of replications necessary to reduce the experimental error to any desired limit.

A sown pasture at the Waite Institute consisting mainly of *Phalaris tuberosa* and *Trifolium subterraneum* maintained a level of approximately 0.5 per cent. P_2O_5 and 18 per cent. protein throughout the growing season when cut four times. By January the protein had fallen to 10 per cent. The application of superphosphate increased the phosphorus content of the herbage but did not materially affect the clover/grass ratio. When grown for hay, this pasture contained 4 per cent. protein and 0.15 per cent. P_2O_5 . The grass yield obtained from the four cuts was approximately the same as that obtained from the hay cut so that the total uptake of phosphorus and nitrogen was considerably greater under grazing conditions.

The influence of the stage of growth on the nutritive value of herbage first shown with pure species in pot culture has been clearly demonstrated in the management of irrigated sown pastures at Wood's Point. Under intensive culture and a 28-day rotational grazing a phosphorus-rich pasture was obtained which was sufficiently unbalanced by reason of its high protein content to cause dietary troubles in the stock. The extremely narrow nutritive ratio of the ration could have been restored to a more normal value by feeding a supplement of carbohydrate-rich material, but the same result was accomplished by feeding off the pasture at a later stage of growth, that is, by the adoption of a less frequent grazing rotation. Six-weekly and bi-monthly rotations were tried, the latter being found to give the greatest yield and to furnish an improved ration having a nutritive ratio of approximately 1:2.8 and a net energy value of 44.8 cal. per 100 lb.

The investigation of the effect of stage of growth on the chemical composition of *Phalaris tuberosa* with and without manurial treatment has been the subject of a pot culture experiment in which the distribution of the constituents in the leaf and stem, butts and roots has been determined. The nitrogen and phosphorus content of the leaf and stem decreased as the plant approached maturity, part at least being translocated to the butts in which an increase in these constituents was recorded.

Experiments carried out with a view to determining the influence of frequency of cutting on the chemical composition of *Lolium perenne* have shown that phosphorus and protein are maintained at a high level throughout the season under a system of three-weekly cuts but the grass becomes progressively poorer in these constituents with less frequent cutting.

Of special interest is the study of the association between legumes and grasses

in pastures. Pot experiments in which a grass and legume are grown in combination under various cutting treatments and at different levels of nitrogen and phosphorus have afforded material for a chemical study of the problem. In the case of *Phalaris tuberosa*, associated with *Trifolium subterraneum*, phosphorus dressings alone had very little effect upon the yield but increased the phosphorus content of the plant to an extent dependent upon the heaviness of the dressing. The addition of nitrogen, however, resulted in an immediate response in yield, the increase being a function of the amount of nitrogen added. The clover, however, not being subject to such limitations of nitrogen supply, gave increased yields with increasing increments of phosphorus, the percentage of phosphorus in the plant remaining unaffected by either nitrogen or phosphorus. Similar trends were found in the case of the protein content, the yield of protein from the grass being a function of the nitrogen dressing, that from the legume a function of the phosphate dressing.

While much is known concerning the nitrogen supply in arable soils, little effort has been directed towards the study of soil nitrogen under grassland. In 1935 a study was made of the fluctuations of ammonia and nitrate nitrogen in a soil supporting an established pasture of *Phalaris tuberosa* and *Trifolium subterraneum*. Under grassland conditions ammonia nitrogen appears to be maintained at a higher level than nitrate throughout the season.

Other activities have included the analysis of pastures from Jemalong, N.S.W. and from "Elderslie", Queensland. At the latter station samplings are being carried out with a view to determining the influence of season on the chemical composition of a pasture consisting predominantly of Mitchell grass.

4. BACTERIOLOGY.

Since the beginning of 1935, the subject of bacteriology has been developed at the Waite Institute in two specific directions. At the end of 1934, the Wine Overseas Marketing Board referred to the University of Adelaide the problems associated with the keeping qualities of fortified wines intended for export. This work is carried on under a committee of the University, and the officer concerned is stationed at the Waite Institute. A bacterial organism concerned with the trouble has been isolated from so-called diseased wines and its characters established. The organism has a high tolerance towards alcohol, and has a narrow optimum range of hydrogen-ion concentration. Wines vary remarkably in their susceptibility towards infection, a property which may be associated with the special nutritive needs of the organism. The problem of susceptibility is one for further investigation.

The study of the nodule organisms of leguminous plants in so far as these are of importance to Australian crops has been begun as part of the activities of the Soils Division. The crops of greatest immediate interest have proved to be lucerne,

subterranean clover and tick beans. Lucerne has been found to benefit materially by inoculation with suitable cultures of *Rhizobium* on such virgin soils of low fertility as the Willalooka Sand. The conditions which make for profitable inoculation in the older established areas are the subject of further investigation. Subterranean clover presents an interesting problem in that strains of *Rhizobium* suitable for red and white clovers are not necessarily efficient on subterranean clover. The isolation and testing of such strains on different species of *Trifolium* present interesting possibilities. There is some evidence that inoculation of subterranean clover is likely to be an important factor in the development of pastures on Kangaroo Island. Tested cultures of *Rhizobium* suitable for the inoculation of subterranean clover have been made available to State Departments of Agriculture.

Entomology

The main work of the Department of Entomology during the period since the previous Report has been centred round certain major insect problems of agricultural and horticultural crops in South Australia. The aim has been to establish accurate knowledge about the lives and habits of the insects concerned. This has been done by means of controlled experiments in the laboratory, and systematic observations and experiments in the field. The development of sound methods of the control of our insect and allied pests is dependent upon the establishment of this detailed information. Close co-operation is maintained with the State Department of Agriculture; advisory service is given to the Department on entomological matters. Agricultural Department officers render considerable assistance in obtaining records relating to insects observed on crops. These records are published biennially; the third series covering the period June 1932 to June 1934 appeared in the Journal of the Department, March 1935 (Publication 74).

Certain entomological problems which are being investigated such as the apple thrips (*Thrips imaginis* Bagnall), the black-tipped locust (*Chortoicetes terminifera* Walk.) and plague grasshoppers, are also important in other States of the Commonwealth. Investigations on these problems are being developed in close co-operation with the entomological workers of the Commonwealth Council for Scientific and Industrial Research, and of the various State entomological services.

Owing to the nature of the climate in South Australia, which is characterized by winter rainfall and summer drought, weather plays an important part in affecting the seasonal occurrence of insect pests, and their abundance. A detailed study has been made of the relationship between meteorological records and fluctuations in the number and distribution of particular economic species. Rainfall, atmospheric humidity and temperature greatly affect the conditions of the physical environment in which insects live, thereby restricting or favouring their multiplication. The basal information which has been established by these investigations has a wide application to the ecology of animals and plants throughout Australia.

An account of the researches carried out in the department may be conveniently grouped under four headings:

1. Entomological problems of pasture and cereal crops.
2. Entomological problems of orchard and garden crops.
3. Miscellaneous investigations.
4. Studies on insects in relation to climate.

1. ENTOMOLOGICAL PROBLEMS OF PASTURE AND CEREAL CROPS.

(1) The "Lucerne Flea" (*Smynthurus viridis*).

The work on lucerne flea which was described in the previous Report has been completed. The information on the biology of the insect and its control, which was

established by controlled experiments in the laboratory and in the field, was applied to the lucerne flea problem in Australia. A full account of the work was published in 1934 (C.S.I.R. Bull. No. 79). The predaceous mite *Biscirus lapidarius* Kramer, which was originally reported as a predator of the lucerne flea in Western Australia, has been found to occur in South Australia. Specimens were obtained at Kybybolite in September 1935, and at Tweedvale in June 1936. Specimens of the mite were received from Western Australia in July and August 1933 through the Council for Scientific and Industrial Research; they were placed in certain districts in South Australia (*vide* Davidson, J. Dept. Agric. S. Australia, 1933, *Bull.* 286). The presence of the mites in the two localities referred to above was not associated with these introductions. Although the species of mite occurs naturally in South Australia it does not appear to be widely distributed in this State. The species was found in very large numbers in May 1935 in a paddock near the Waite Institute. Eggs were found in abundance under the bark of red gum trees (*Eucalyptus rostrata*) in the paddock; they extended up the trunk to about six feet from the ground. Owing to the presence of the mite in such large numbers, it would seem that the species had been there for some years. On the other hand, specimens received from Western Australia in August 1933 had been placed in a lucerne paddock about 500 yards away. Considering the density of the population present in the new situation, and the extent of the area over which the mites were distributed, it seems unlikely that these conditions could have developed in such a short period. Up to the present time there is no definite evidence available from observations in South Australia that the mite, *Biscirus lapidarius*, exerts a controlling influence over the multiplication of the lucerne flea. The correct interpretation of field observations on this matter is complicated owing to the influence of weather on the physical environment in which the insect lives; weather changes may markedly retard or favour its increase in numbers.

(2) *The Red-legged Earth Mite (Halotydeus destructor* Tucker).

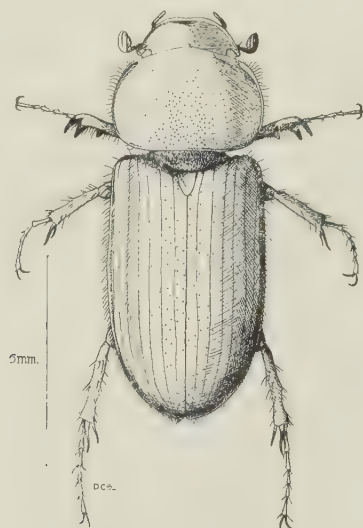
Work on the biology of the pest, which was referred to in the previous Report has been continued. A general account of the results of the investigation is given in Publication 59. This mite is widely distributed over the better rainfall areas of the State; it is particularly troublesome to garden crops on the Adelaide plains. It is a serious pest of clovers in some pastures, but up to the present this occurs only in local situations. Experiments on the development of the eggs in relation to temperature and moisture show that excessive wetness is unfavourable; the eggs become distended and burst, so that there is heavy mortality under these conditions. On the other hand considerable moisture is essential for egg development; dryness may result in heavy mortality of developing eggs, although certain eggs remain dormant and viable during the dry summer months. These facts illustrate the significance of soil type in relation to multiplication of the mites. The species does not increase to serious numbers on

heavy clay soils; sandy or loamy soils favour heavy infestations. The egg has a relatively short incubation period. For instance, if moisture is favourable, at 75° F. (24° C.) it hatches within 2½ days after being laid; at 63° F. (17° C.) it takes 5 days, and at 50° F. (10° C.), 8½ days. The mites lay their eggs on the undersides of the leaves of the food plant; females which were examined contained from 19 to 55 eggs each. The mites congregate particularly in moist situations below vegetation when the weather is dry. No natural enemies of the mite have been discovered.

In small garden areas control can be obtained by garden sanitation and weed control, together with spraying where necessary. In pastures control measures are difficult to apply owing to the large areas involved. The reader should refer to the recommendations given in the paper noted above.

(3) *The Aphodius Pasture Grub (Aphodius tasmaniae Hope).*

With the scientific development of pastures in the South-East of the State, and increase in their stock-carrying capacity, new "pest" problems may be expected. The *Aphodius* grass grub is the early stage (larva) of a scarab beetle (see



Aphodius tasmaniae Hope. Adult Beetle.

It is dark shining brown in colour. The larva attacks pastures.

figure), which has developed as a pest of pastures in the South-East during recent years. The beetles fly in large numbers at night, during February; they are readily attracted to light so that flights have been often recorded. The females lay eggs on the soil usually in bare areas in the pasture, on sheep camp sites or at

places near fences which are fouled with dung. The young grubs hatch out with the autumn rains. As they increase in size they make vertical burrows in the soil in which they live. They emerge at night and feed on the seedling grasses and clovers in the pasture, which they may strip quite bare. The grub also excavates soil from the burrow and scatters it over the surface of the denuded pasture. This damage goes on into the spring. By early summer the grubs pupate in their burrows and eventually the adult beetles emerge and take flight about the end of January or early in February.

This insect is one of the dung scarab beetles; its increased development as a pest is associated with increased stocking. Over large pasture areas, the most promising control measures consist of appropriate and well-timed cultivation of infested areas so as to destroy the early stages of the beetle in the soil. Deep cultivation in early summer and during dry spells in the autumn will reduce the numbers of the pest in the infested areas.

This pest is often destructive on lawns. In restricted areas the pest can be readily controlled by spraying the lawn or pasture with lead arsenate (7 lb. to 100 gallons of water). It will of course be necessary to prevent the access of stock to sprayed areas. The present situation regarding the *Aphodius* grub problem is discussed in Publication 54.

(4) *The Black-tipped Locust (Chortoicetes terminifera* Walk.).

A widespread plague of this locust developed over the northern areas of South Australia during the summer and autumn of 1933-34. The plague reached its peak during 1934-35 when the swarms extended southwards over the agricultural areas of the State. The infestation also extended over parts of Victoria, New South Wales and Queensland. These plagues have occurred from time to time during the history of settlement in South Australia, and they cause extensive damage in the wheat belt and agricultural areas. The occurrence of these locust swarms in the southern areas of the State is only temporary, extending over one or two years.

Observations have been made on the habits of the species and its ecology (Publication 58). The adult insect is of a general dark-brown colour, but green forms occur in swarms as solitary individuals; the male is somewhat smaller than the female. The characteristic feature of the species is the well-defined dark pigmented area at the tip of each of the hind wings; the inner face of the femur is reddish; the greater part of the tibiae is also reddish (see figure). The eggs are laid in pods in the soil to a depth of $2\frac{1}{2}$ to 3 inches, the average number per pod being about 40 eggs. The eggs do not develop in dry soil and may remain dormant for many months; they hatch when the soil moisture and temperature are favourable. The early wingless stages (nymphs) undergo five moults before they become winged adults; the time of complete development varies according to temperature,

but under summer conditions in South Australia, when moisture is adequate, the life cycle is completed in from four to six weeks.

It appears that this insect may be always found as solitary individuals in the drier areas of the State; in certain years the species becomes gregarious and forms swarms. With favourable rainfall these swarms may increase over one or more years and extend southwards over the agricultural areas of the State. Under these conditions eggs are laid by the swarms in areas known as "egg beds"; the hoppers which hatch out migrate in dense bands or swarms, feeding on suitable vegetation.

During the recent plague, the Department of Entomology, in co-operation with the Department of Agriculture, made recommendations for dealing with the



Chortoicetes terminifera Walker. Female. The black-tipped locust. The hind legs are chiefly red.

locust plague, and the "Noxious Insect Act 1934" was passed by Parliament. Regulations under this Act for the carrying out of control measures on a communal basis were promulgated by the Executive Council. The Regulations defined the responsibilities of District Councils, Municipalities and occupiers of land, with reference to the carrying out of compulsory measures set out in a schedule accompanying the Regulations. An account of these measures was published in the Journal of the Department of Agriculture (Publication 55).

A detailed investigation of the locust and grasshopper problem is in progress. Survey tours are being made throughout the State in order to establish the areas which the insect permanently inhabits (reservation areas). These areas are situated in parts of the drier regions, north of the wheat belt, and in non-plague years the insects are present only as solitary individuals or small, loose swarms (Publications 57, 79). The development of swarms leading to plagues in certain

years appears to be associated with rainfall in particular seasons. Experiments are being made with a view to understanding the causes which bring about these plagues, particularly with reference to rainfall, temperature and atmospheric humidity on the behaviour of the insects and their increase in numbers. In this connection a survey has been made of the physiography, climate and vegetation of South Australia, since they determine the character of the physical environment of the insect (Publication 56). The results of these investigations should enable us to be adequately warned of impending plagues before they assume widespread proportions.

(5) *The Plague Grasshopper* (*Austroicetes jungi* Branscik).

The plague grasshopper is a smaller species than the black-tipped locust. The females are of a general brown colour with darker bands on the femora and with clear hind wings (see figure). The males become bright yellow in colour.

In general habits the species resembles the locust, but it has a comparatively restricted range of migration from the areas where the swarms develop. It



Austroicetes jungi Branscik. Female. The hind legs are chiefly yellow.

occurs particularly in parts of the southern pastoral country and northern areas of the wheat belt. During 1934-36 it has been present in large swarms over many square miles of country particularly around Wilmington, Quorn, Orroroo, Peterborough, and in the Flinders Range and northern parts of Eyre Peninsula, but it has a wide range over the State in the northern areas of the wheat belt (Publication 79). The wingless hoppers wander about in dense swarms and may cause considerable damage to pasture grasses and cereal crops. A detailed investigation is being made of this species. As with the black-tipped locust, it develops into serious

swarms in certain seasons at irregular intervals, which is closely associated with rainfall in particular seasons. It develops to plague proportions more frequently than is the case with the locust, and its permanent breeding grounds appear to be more clearly defined. Control measures will be the same as for the locust.

In connection with these investigations, acknowledgment is made of the valuable assistance of the Council for Scientific and Industrial Research. A utility truck, specially fitted up for travel in rough country, has been placed at the disposal of the Entomology Department for the field work. Running costs are met from a grant made by the Government of South Australia. These provisions have made possible a much more thorough and extensive investigation than would otherwise have been the case.

In addition to these major problems, attention has been given to the occurrence of a plague of field crickets (*Gryllus servillei* Sauss.) in pastures in parts of the South-East. The crickets appear to be confined to black, silty soil which is sticky when wet and in which cracks develop 9–12 inches deep when dry. In the infested areas the pasture grasses, particularly sown rye-grass, were eaten off. Bran mash arsenic poison baits should be used to control infestations in future.

Other investigations have dealt with the possible association of insects such as the boll-worm (*Heliothis armigera*) with the non-setting of lucerne seed in the northern lucerne areas, and the occurrence of the Hepialid moth *Oncopera fasciculata* Walk., whose larvae ("grass grubs") may cause damage to pastures in parts of the South-East.

2. ENTOMOLOGICAL PROBLEMS OF ORCHARD AND GARDEN CROPS.

(1) *The Apple Thrips* (*Thrips imaginis* Bagnall).

Investigations on this important pest which were referred to in the previous Report have been continued. Research on the biology of the species has been completed, on which control measures have been based. The results of these researches have been published in technical papers by various members of the Thrips research team (see Publications 60–67).

The essential feature of this species, as regards the apple crop, is that it occurs in plague numbers in particular years, during the period of the flowering of apple trees. The insects invade the unfolding blossoms and damage the reproductive organs of the flower thereby affecting the setting of fruit. A study of the problem has been carried out in Victoria and in South Australia. The species may be found in flowers in the Adelaide area, all the year round, but the numbers fluctuate according to the favourableness of the period of the year. During the past five years daily counts have been made at the Waite Institute of the number of adult thrips present on roses. Graphs illustrating these records are shown in accompanying figure. The points on the curves represent the average number of thrips per rose (average of 20 roses) taken during a ten-day period. Commencing

with the mid-summer period it is seen that thrips are present in small numbers during the hot dry summer months. This is associated with dryness of the soil which is unfavourable for the pupal stages; dryness also results in fewer flowers being available compared with the spring period. In the autumn, about May or June, the number of thrips increases; this is referred to as the "autumn rise". The magnitude of this increase depends upon the favourableness of the autumn

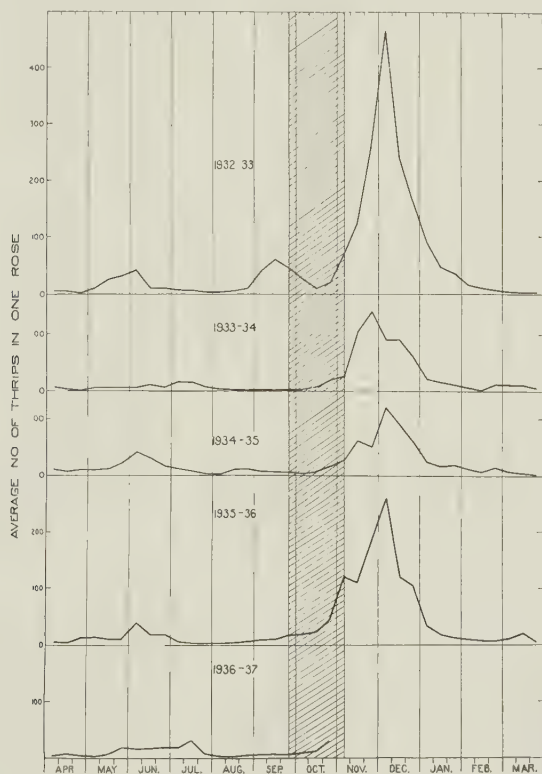


Chart showing the fluctuations in the numbers of *Thrips imaginis* for five years at Adelaide. The period during which apple trees are in blossom is shown by hatching.

weather, particularly early autumn rains; this affords favourable soil moisture for the pupae and the growth of plants. As autumn advances into winter the numbers of thrips decrease. This is due to low temperature which retards development and restricts the insects' activities. The insects pass the winter as pupae in the soil or as dormant adults in sheltered situations; some active individuals may be found in flowers, especially on warm sunny days.

With the advent of warm spring days, there is a marked increase in the number of active thrips. This is due to the emergence of adults from over-wintering

pupae and to renewed activity of dormant adults. The early spring rise in numbers is referred to as "the first spring rise"; it may occur early or late according to the favourableness of the prevailing weather, particularly temperature. The extent of the first spring rise depends upon the extent of the previous autumn rise, survival during the winter and the character of the prevailing spring weather.

The first spring rise is followed by a further increase in numbers, which is referred to as the "second spring rise". This rise is due to the development of a further generation of individuals following on the first spring rise. The date of its occurrence and extent depend upon the date and extent of the first spring rise and the favourableness of the spring weather. With the advance of the dry summer months the numbers of thrips decrease.

It is seen from accompanying figure that the general trend of the fluctuations in the numbers of *T. imaginis* is the same every year but the actual numbers present during the spring period vary from year to year. This is due to changes in the weather. In those years in which the weather favours a large increase in the numbers of thrips as a second spring rise, early in October, heavy infestation of apple blossom may be expected. With the development of a further generation of the insects during November or December, bush and berry fruits, garden flowers and vines may be heavily infested.

The important weather features which favour the occurrence of the apple thrips in economic numbers in spring are early autumn rains and a wet autumn, followed by an early and sustained warm spring. The date of the occurrence of the "first spring rise" and its extent are important guides to the degree of infestation which may be expected during the spring. Where conditions favour the development of large numbers of thrips as a second spring rise early in October, a heavy infestation of apple blossom may be expected. The thrips will be widely distributed over the infested area. They will move actively on hot dry days and infest flowers and blossom. With most varieties of apple the thrips enter the buds at the base of the petals, before the buds open; they damage the stamens and pistil; if thrips are numerous, the blossom may not set fruit. They also feed on the exposed portion of the petals, causing them to turn brown. When the buds open, the insects continue to infest the blossom. During the thrips plague in the spring of 1931, 100-150 thrips were present in individual apple blossoms.

During a heavy infestation, it is impracticable to aim only at killing the thrips infesting the blossom, since the insects are abundant over a wide area. The aim should be to drive the thrips out of the blossoms, and protect the latter during the critical periods of the invasion by the application of suitable dusts or sprays. It is important to anticipate movements of the thrips, and suitably time the application of the insecticide. It is best if the protective cover can be applied when an invasion is imminent, which will normally occur during hot days.

During the period that the Thrips Investigation has been in progress, the

numbers of thrips in the spring have been too small to allow of adequate field trials being made with insecticides. By means of laboratory and restricted field tests, certain insecticides have been selected for extended field trials when the opportunity offers. Future work on this problem will be confined to orchard trials with appropriate dusts and sprays. Preliminary tests have shown that insecticides containing derris and pyrethrum may give a measure of control.

It is well to remember that many factors are concerned with the setting of fruit on apple trees. The fruit buds are differentiated some nine months prior to blossoming, and the health of the tree during this period is important in relation to the production of strong healthy blossom; weather during the period of blossoming and the viability of the pollen are also important matters. The evidence indicates that these factors play an important part in the setting of fruit and require further investigation.

In addition to the technical papers referred to above a brief survey of the results obtained in the thrips investigation is given in Publications 68 and 69. A general account has been prepared of 15 species of thrips of economic importance in Australia (Publication 70). The investigation has been carried on under a co-operative arrangement with the Council for Scientific and Industrial Research, the Waite Institute, the Thrips Investigation League, and certain of the State Departments of Agriculture.

(2) *Thrips on Tomatoes.*

It was pointed out in the previous Report that the species of thrips identified as *Frankliniella insularis* Franklin, which is a vector of spotted wilt disease of tomatoes in South Australia, may prove to be different from Franklin's species which was originally described in 1908 from specimens taken in Barbados. It has now been established that the Australian insect is a new species and probably indigenous to the country (Publication 70). The common onion thrips (*Thrips tabaci* Lind.) is also a vector of tomato spotted wilt.

(3) *Thrips on Gladioli.*

The gladiolus thrips has been troublesome to growers of gladioli during the past few years; the insects damage the surface of corms in store, producing "russetting"; they also seriously damage the leaves of the growing plants, giving them a "silvered" appearance, and also the flowers, which results in retarded growth and distorted blooms. This species was widely known as *Taeniothrips gladioli*, an appropriate name given by Moulton and Steinweden in 1931 to specimens collected on gladioli in Canada. It has been shown, however, that this species is the same as specimens collected from carnation flowers at the Waite Institute in 1928, and described by Morison in 1930 as *Taeniothrips simplex* (Publication 70). Treatment of infested corms by fumigation and spraying of infested plants from an early stage, as deemed necessary, should be carried out.

(4) *Pittosporum Bug*.

The ornamental shrub (*Pittosporum undulatum*) is widely planted as a garden shrub and hedge plant in South Australia. During recent years it has suffered widespread damage owing to the habits of a species of shield bug (family *Pentatomidae*). The beautiful green colour of the leaves of this shrub is destroyed owing to the bugs feeding on them, giving them a mottled appearance. The growth of the shrub is retarded and the plants may be killed. It has been found that the insect is a native species of *Menida*, new to science, and was probably originally associated only with wild native species of *Pittosporum*. The eggs are laid in rows on the leaves; there are two generations in the year and the adults congregate under debris or in suitable shelter during the winter months. Garden sanitation and application of suitable contact insecticides against the young insects are necessary to control this troublesome pest.

(5) *The Curculio Beetle*.

The common curculio beetle (*Otiorrhynchus cribricollis* Gyll.) is a widespread pest on many garden plants. The adult beetles emerge in spring from their winter



Damage to almond foliage by the Curculio beetle (*Otiorrhynchus cribricollis*).



Roots of three-year-old Ash injured by the larvae of *Otiorrhynchus cribricollis*.

hiding places from pupae in the soil; they become particularly evident about the end of November. The beetles feed at night on the leaves of garden shrubs and young fruit trees; when present in large numbers serious damage may be done as is shown in accompanying figure. The insects hide beneath the soil surface during the day time. The eggs are laid in the soil and the larvae feed on roots of various plants; during the dry summer they may go down to a depth of three or more feet to escape excessive dryness. An example is illustrated in the accompanying figure of serious damage to the roots of young ash trees in a nursery near Adelaide caused by grubs (larvae) of this beetle. When soil is heavily infested with early stages of the beetle, soil fumigation with carbon-bisulphide or para-dichlorobenzene may be necessary. Trapping the adult beetles by means of an appropriate poison bait is effective in reducing their numbers.

(6) *The Green Peach Aphis* (*Myzus persicae* Sulzer).

Observations have been continued relating to the influence of weather on the intensity of infestation of peach trees by this pest in the spring. There has been no widespread infestation in the State during the years under review. Counts were made of the number of eggs present on peach twigs in June each year. In one orchard the number per twig (average of 50 twigs) was found to be .7 (1934); .3 (1935); 4.2 (1936). In those orchards in which experience has shown that control measures against this pest must be carried out, tar distillate spray applied in mid-winter has given efficient control.

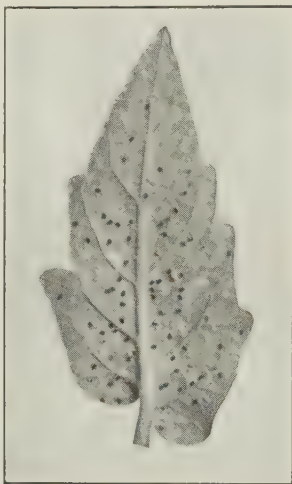
(7) *White Fly on Tomatoes.*

The white fly (*Trialeurodes vaporariorum* Westwood) is a serious pest of glasshouse tomatoes. In addition to the effect of these insects on the plants, due to their sucking out the juices from the leaf tissues, they foul the plant by means of the sugary liquid which they excrete over the leaves and fruit. The pest may be controlled by cyanide fumigation; where this is not carried out the insects rapidly increase in numbers under the favourable warmth of the glass houses.

In July 1926, white fly in a small glasshouse in Hertfordshire, England, was found to be parasitized with a minute Chalcid wasp. This wasp proved to be a species known as *Encarsia formosa* Gahan, which was recorded first in 1924 from Ohio in the United States. Later on the species was found to be present in Bermuda where it is stated to control the white fly completely. This wasp parasite has now become world-famous and has been sought after by many countries for the purpose of controlling white fly.

Through the helpful co-operation of the Division of Economic Entomology of the Council for Scientific and Industrial Research, living material of this parasite was obtained in September 1936. Colonies are being raised on white fly on tomato plants in the insectary at the Waite Institute. Arrangements have been made with the Horticultural Branch of the Department of Agriculture for the parasite to be placed in suitable situations to see if it can be established here.

The wasp is about one-fortieth of an inch long; the posterior end of the body is yellow; the anterior portion being dark brown. Males are usually rare so that the female lays eggs which develop without being fertilized. The female wasp lays an egg in or on a young white fly (pupa); the whitish pupae are found infesting the under side of the tomato leaves. Only one egg is deposited in a white



Under side of tomato leaf showing White Fly pupae (black) parasitized by wasp *Encarsia formosa*, and unparasitized pupae (white).

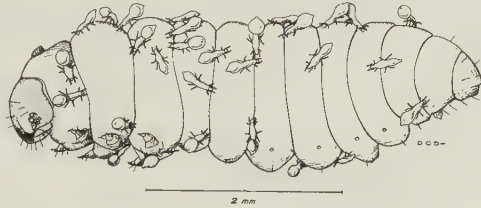
fly pupa; a female lays about 50 eggs. Within two or three days the young parasite (larva) hatches from the egg and proceeds to feed on the tissues of the white fly pupa which turns black (see figure). These black pupae are diagnostic of the presence of the parasite. Within about two to three weeks the parasite is full-grown and emerges through a hole in the skin of the devoured white fly pupa.

3. MISCELLANEOUS INVESTIGATIONS.

(1) *The Hay-itch Mite (Pediculoides ventricosus Newport).*

During the past few years reports have been received from various sources of a skin affection occurring amongst workers handling certain agricultural products, notably grain, hay and chaff. The trouble manifests itself chiefly as an irritating itch, known as "hay-itch". An investigation of this problem has revealed that it is associated with the presence of a minute mite in the materials. This mite lives as an ecto-parasite on the larvae of many insects, and is commonly associated with the larvae of the grain moth in infested cereal materials (see figure). The males are about $\frac{1}{100}$ th inch in length, but mature females become greatly distended by the development of young mites in their bodies (see figure). Records from the

literature show that this mite is associated with skin irritation amongst workers handling such material in warm countries in various parts of the world. In Australia, the larvae of the Angoumois Grain Moth (*Sitotroga cerealella*) appears to be the chief source of infestation. Owing to the grain present in cereal hay stacks, the moths may increase in large numbers and the parasitic mites similarly increase in numbers. When the materials are being handled, particularly in hot weather, either in the stack or in the chaffing house, the minute mites get on to the



Hay itch mites (*Pediculoides ventricosus*) beginning to feed on a larva of the Grain Moth (*Sitotroga cerealella*).

bodies of the workers; the irritation produced by their presence may result in a skin eruption or dermatitis. However, man is not a normal host and the mites do not persist long on the human body. Workers suffering from "hay-itch" should follow treatment recommended by a physician. Where practicable, measures should be taken in farming practice to reduce the infestation of materials by insects. With cereal hay it is the standard practice in Australia to cut the crop some time after flowering, since hay chaff is favoured in which developed grain is present. If the crop is cut early (at flowering time) the material will not be favourable for the grain moth, in the absence of whole grain. The subsequent stack will not be favourable for the grain moth. It may be remarked that cereals possess a higher nutritive value at flowering than at maturity of the grain; although the actual yield of hay may be less when cut at the flowering stage, it will have a higher feed value. These matters are discussed in Publication 71, which gives an account of the research carried out on the "hay-itch" problem. An account of its relation to man in Australia is given in Publication 72.

(2) *The Marsh Mallow Weevil* (*Ethemaia sellata* Pascoe).

The association of insects with weeds is of considerable interest owing to the few known examples in which particular species exert control over the multiplication and spread of certain weeds. The classical example of the control of prickly pear in Australia by the cactus moth, *Cactoblastis cactorum*, is common knowledge. An interesting example of the temporary destruction of areas of Marsh Mallow (*Malva parviflora* L. and *M. nicaeensis* All.) by the above weevil has been investigated near Adelaide. An account of the observations is given in Publication 76.

The weevil is widespread, and has been found attacking these weeds throughout the better rainfall areas of the State. Both the adult weevil and the larvae feed on the plants, which may be completely defoliated. Unfortunately these weeds have vigorous powers of recovery. They rapidly make regrowth when the attack is over which occurs when the insects develop to maturity, and having eaten out the plants, disperse from that particular situation.

4. INSECTS AND CLIMATE.

The insect fauna of an area is largely determined by the nature of the physical environment, in which temperature and moisture play a dominant part. Biotic factors such as food and competition are important additional considerations. These varied forces bring about fluctuations in the numbers of insects in an area. Considerable attention, therefore, has been given to the influence of particular elements of climate and weather in Australia, on the distribution, seasonal occurrence and abundance of particular species of economic importance. By means of analyses of records of rainfall, temperature and atmospheric humidity in Australia, the continent has been mapped into areas in which the average moisture and temperature "conditions" are known, month by month. By means of suitable combinations of these areas various zones have been defined (bioclimatic zones) in which the essential elements of climate affecting the physical environment of insects have been assessed. In this way comparisons can be made of the insect fauna in zones having similar or different environments. The principles concerned may be applied to many aspects of animal and plant ecology in Australia. An account of these studies is given in a series of papers which is listed under the section "Climatology" (Publications 80, 82-84). The methods which have been developed have been applied to a study of the possible range of distribution of the "lucerne flea" as an economic insect in Australia. They have been used in an examination of the fluctuations in numbers of the "apple thrips" throughout the year, with the object of determining, by early spring, the extent of the infestation of apple blossom which may be expected later in the spring. They are being used in investigations relating to the causes underlying the occurrence of locust and grasshopper plagues in Australia (Publications 56 and 58).

Plant Pathology

The losses in production which result from plant diseases are so evident to growers that there is a constant demand for information on the best means for preventing these diseases.

The work in Plant Pathology at the Institute falls into two sections. In the first place, a service is provided for the identification of all plant diseases occurring within the State and this information is supplemented with advice on methods of control. This advice, where possible, is based on actual experience with the disease locally, and in other cases on practices which have been found effective abroad and have been reported upon in the scientific literature dealing with the subject.

The advisory service usually operates through officers of the Department of Agriculture with whom close contact is maintained. Besides enabling growers to obtain all the advice available concerning plant disease control, this advisory service has provided information on the nature, prevalence and distribution of plant diseases in this State. This information, in the form of notes on the prevalence of diseases in South Australia, has been published biennially in the *Journal of Agriculture* (Vols. 34, 36, 38). The time is approaching when it will be possible to publish a survey indicating fairly adequately what plant diseases are present in the State.

The second line of work is concerned with investigations into the nature, life history, and ultimately the best methods of controlling the economically more important plant diseases occurring locally. Further details concerning this work are given below under the headings of the particular diseases concerned.

Investigations on two important diseases, viz. "Manganese deficiency" in oats and barley and "Tomafo spotted wilt", which were initiated and were pursued for some time in the plant pathology department, are reported upon elsewhere in this Report.

(1) *Cereal Diseases.*

Wheat is the most important crop in South Australia. Of the diseases affecting wheat, some, like "rust" or bunt" affect primarily the above-ground parts. Other, such as "eelworm", "Rhizoctonia root-rot" and "take-all", affect the plant because of an attack on the roots. This latter group of diseases is more important under South Australian conditions. The various foot and root-rotting diseases of wheat are distinguished from one another by a determination of the disease-producing organism found associated with each. There is probably some artificiality about this system but in justification it may be said that it does help to simplify the experimental study of these diseases.

At the Waite Institute, an extensive study of wheat specimens from all parts of the State revealed the existence of most of the fungi known to cause root-rotting diseases, but the view developed that *Ophiobolus graminis* known to be the cause

of "take-all" was the principal cause of crop losses in this State. In accordance with this view, this fungus has been used in most of the investigational work that has been undertaken.

(A) "TAKE-ALL" OF WHEAT.

"Take-all" is a disease which affects plants at all stages of growth. Where the plants are affected whilst young, the disease often assumes a circular patch form and many plants die without producing heads. On the other hand, plants may produce ears but then, instead of filling with grain normally, the head bleaches and little or no grain is formed. In this form of the disease, known as "white heads" or "hay die", affected plants may occur in patches or be more or less thickly scattered throughout a crop. This is the most dreaded form of the disease, and when it occurs it often causes serious losses.

"Take-all" starts as a disease of the roots and infective root material from a previous occupant of the land constitutes an important source of infection. It is important then to discover which of the plants that may grow naturally on the



A large "take-all" patch at Karoonda, South Australia.

wheat lands of South Australia are susceptible to "take-all". To obtain information on this point, a search has been made for plants other than wheat which are naturally infected by "take-all". This has been supplemented by pot experiments to test the susceptibility of these plants under artificially controlled conditions. Species which have been shown to harbour the "take-all" fungus and in which the disease has been induced artificially, include *Hordeum murinum*, *Festuca myuros*, *Bromus villosus*, *Bromus madritensis*, *Bromus rubens* and *Lolium subulatum*. Species from which the "take-all" fungus has been isolated but in which the disease has not yet been induced include *Avena sativa*, *Cynodon dactylon*, *Danthonia setacea* and *Hordeum maritimum*. On the other hand, "take-all" disease has been developed in *Lolium temulentum*, *Lolium rigidum* and *Stipa setacea*, though natural infections on these hosts have not yet been seen. The attempts so far made to infect Mediterranean grass (*Schismus barbatus*) and perennial rye-grass (*Lolium perenne*) have been unsuccessful.

It is clear then that a number of the grasses are susceptible to "take-all" and the question arises as to how long these remain infective. Steps are being taken to obtain this information by keeping diseased roots and other material carrying the fungus in contact with soil under natural conditions. This work is being done at three centres having different soils and climates, samples being taken from time to time to ascertain whether the material is still infective.

In the soil the "take-all" fungus, whether surviving in root material or attacking a plant, has to contend with a factor the importance of which has only been recognized in recent years. This factor is described as "biological antagonism" and is considered to be associated with the activities of the vast numbers of micro-organisms inhabiting normal soils. Much of the variation in the prevalence of "take-all" from soil to soil is now thought to be due to the operation of this factor. In the last Report, reference was made to Publication 113, and a graph illustrating an inverse relation between bacterial numbers and susceptibility to "take-all" was given. A good deal more work along these lines has been undertaken, and it has revealed that the problem is not quite as simple as these results suggest. Work on this problem has progressed in two directions. In the first place, experiments were conducted using known mixtures of micro-organisms, one of which was *Ophiobolus graminis*, and these mixtures were then used to inoculate a standardized sterile sand in which wheat was grown. In the second method, which at present offers more promise, the microbiological equilibrium is affected by the addition of supplements designed to influence particular elements in the soil flora. The relative effects of these treatments on the development of "take-all" are then measured, and it is hoped in this way to obtain more precise information on the particular factors affecting the activity of the "take-all" fungus. A review covering this field till 1934 has been published (Publication 42).

Experimental evidence has made it quite clear that one source from which wheat plants may contract "take-all" is the root material from diseased plants of

a previous season, but this may not be the only source. It has been observed (p. 107, last Report) that in certain seasons the spore cases of the fungus ripened on diseased plants in early "take-all" patches by September or October and that in rainy weather the spores were shot out into the air and blown about in thousands. It was thought that this observation might provide a clue to the problem of the extensive development of "hay die" which is characteristic of certain seasons. It is obvious that spores produced under such circumstances constitute a source of infection, but their effectiveness in this direction depends on the susceptibility of wheat during its later stages of growth. The direct study of this problem is difficult because hitherto it has not been possible to secure an abundant supply of spore material when required. However, a close study of the nutritional requirements of the "take-all" fungus is being made and there is promise of our being able to secure spore material at will.

Experiments in a slightly different direction, viz., the testing of the susceptibility of wheat at different ages to mycelial cultures of the "take-all" fungus, have been undertaken and others are in progress. These experiments have shown that susceptibility decreases with age.

It has also been found that wheat can be artificially infected at a later period than has been previously reported. The material on which the fungus has been grown is also important in determining its infective capacity.

In the previous Report, under the heading of Uniformity Trials with Cereals in the Field Crop Investigations, reference was made to the effect of soluble phosphate in reducing the percentage of plants seriously affected with "take-all" disease. This effect has been further confirmed for Waite Institute land and steps are being taken to analyse the reasons for this beneficial effect.

In the field, "take-all" usually occurs as circular patches. Experiments undertaken (Publication 53) suggest that this shape is due to spreading of the fungus through the soil in which susceptible plants closely set together are planted, the fungus spreading from root to root. The spread of the fungus in one direction under favourable circumstances probably does not exceed two feet in one season.

(B) BARLEY DISEASES.

Barley grown for malting purposes is among the cereals next in importance to wheat in South Australia. It is little subject to disease, covered smut (*Ustilago hordei*) being perhaps the most conspicuous. In 1935, a series of field trials designed to test the effectiveness of seed treatment was commenced. In these trials, the value of treatments commonly practised, viz., steeping or sprinkling the grain with weak formalin solutions and dusting with copper carbonate, is being compared with the newer organic mercurial dusts "Agrosan" and "Ceresan". This year the work was extended to include "Californian Cape", a variety which is susceptible to stripe (*Helminthosporium gramineum*), another seed-borne disease. The results of this work are not yet ready for publication.

(2) *Gummosis (Die-back) in Apricots.*

In the last Report reference was made to a "die-back" of apricot limbs which was troublesome in a number of Lower Northern apricot orchards. Later surveys have shown that the disease is not confined to this area but occurs in all districts where apricots are grown. The disease generally develops at some intermediate point on a limb in association with a recent pruning cut. Sometimes the tip of



Apricot tree showing typical symptoms of "Gummosis" dieback as found in South Australia.

the leader is affected and dies back a short distance. Where the disease starts in the lower parts of a limb, the early symptoms are often attended with much gumming, hence the common name "Gummosis" used by growers. Accompanying this gum, which generally accumulates on the branches as large drops, there is a death of the bark, frequently associated with a characteristic longitudinal splitting. This splitting occurs near the junction of healthy and diseased tissue and is due to a tearing apart of the diseased and healthy tissue induced by a continuance of growth in the uninvaded tissue. Once this splitting has taken place, further invasion of the healthy bark so isolated is greatly delayed. The wood is freely penetrated and the disease spreads rapidly up and downwards from the point of

infection compared with its spread laterally. Ultimately, practically the whole cross-section of a branch becomes infected. Apparently the disease impedes the supply of moisture to the transpiring leaves because on a tree in this state all the leaves on the branch beyond the diseased region suddenly wilt but remain dry and



Close view of branch from an apricot tree affected with "Gummosis". Note the relation to a pruning cut, the gum exudate and the longitudinal cracking of the bark.

attached to the tree. By the time that this wilting occurs, the disease has usually spread a considerable distance down the branch from the point of infection and may have passed into a larger branch or the butt. When this has happened, the



Cross section of an apricot branch affected with "gummosis" showing growth of the fungus from the wood.

usual practice of cutting off the diseased branch is ineffective for stopping the progress of the disease. Gradually other limbs become involved till eventually the tree is killed. The progress of the disease is not very rapid for a tree may survive for several years after infection has occurred.

A large number of inoculation experiments with apricot branches of varying ages, using pure cultures of a fungus readily isolated from diseased wood, have confirmed the view that this disease is caused by a fungus. The question of the identity of this fungus is not yet settled. Under suitable conditions the fungus produces pycnidia which contain spore-like bodies conforming to those described for the form genus *Cytosporina*, but it is possible that other spores, not yet recognized, are also present.

In addition to studies aimed at elucidating the identity of the fungus, attention is being given to such questions as the types of wound prerequisite to infection, it having been determined already that a wound of some description is necessary. The means by which the disease is spread in the orchard, the capacity of the fungus to infect other orchard trees, and other features in the developmental history of the disease are also being studied. In this work, more than 500 inoculations (including controls) have been made on apricot trees situated at the Hackney and Blackwood Experimental Orchards, and kindly put at our disposal by the Department of Agriculture. Some of the infections have been established for two years now, but results are not ready for publication.

(3) *Eelworm Disease in Tomatoes* (*Heterodera marioni*).

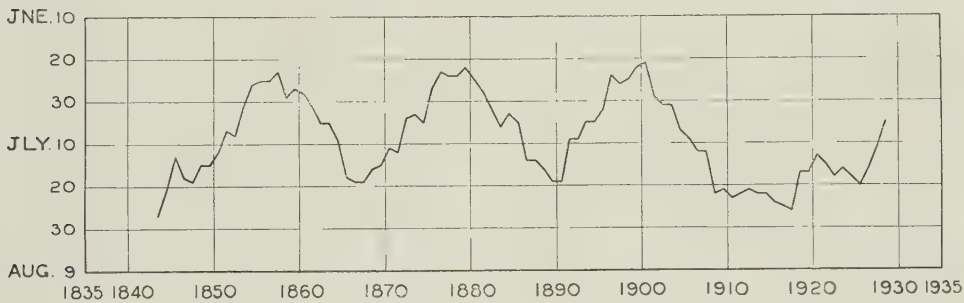
It has been reported from various centres, and particularly from Hawaii, that chloropicrin is an effective agent for the control of this eelworm pest. Since this tomato disease is prevalent in glasshouses about Adelaide, where the tomato-growing industry is a big one, arrangements were made to submit chloropicrin to field trials. This work, started in 1935, has been done in close co-operation with the Adelaide Chemical Co. This year, a machine for injecting chloropicrin into the soil conveniently and rapidly has been developed and the field trials have been greatly increased in scope.

Climatology

(See Publications Nos. 80-86).

In the study of the geographical distribution of plants and of animals and of soils and in the determination of general agricultural policies a knowledge of climatic conditions is of fundamental importance. The factors which are of greatest significance are the amount, distribution and reliability of the rainfall and the temperature and humidity. The rainfall determines whether crops can be grown at all, the temperature the nature of the crops, while temperature and humidity together determine the rate of evaporation, a factor of importance in the water requirements of plants, and in determining the efficiency of the rainfall.

The rainfall records for Adelaide are amongst the longest and most complete in the whole world, and in consequence have afforded material for the study of variability and possible secular changes and periodicities. A statistical study of these records has established two interesting facts; the first is that throughout the 95 years, 1839-1933, the fluctuations in the total yearly rainfall are such as may be expected from a chance distribution, and show no evidence of change, and the



Ten year means of the median of the rainfall sequence, Adelaide.

second more remarkable fact that the seasonal distribution which is so characteristic a feature of our rainfall is subject to a rhythmical movement with a period and amplitude of approximately 23 years and 30 days respectively. In the accompanying diagram, which demonstrates the nature of this periodicity, the curve shows the date of attainment of half of the year's rainfall. In the first few years of the period the seasons were late; thus about 1842 the date upon which half of the year's rainfall was attained was July 28. In the succeeding years the seasons became progressively earlier, reaching their earliest point about 1857, when the corresponding date was June 24. The direction of movement was then reversed, and the seasons became later and later until 1868, after which there was another

reversal of movement and the whole sequence of operations was repeated twice, but during recent years some factor not yet accounted for has disturbed the regularity of the phenomenon.

It is worth noting that the orderly sequence in the movement of the seasons is independent of the amount of rain received from year to year.

The rate of evaporation is measured daily at the Waite Institute from the free water surface of a tank three feet in diameter in accordance with the standard practice of the Commonwealth Meteorological Services. Evaporation so measured can be correlated with the dryness of the air, the best measure of which is the saturation deficiency of water vapour pressure, that is the amount of water vapour which the air will still take up at a given temperature and relative humidity. For 36 consecutive months at the Waite Institute a correlation coefficient of 0.958 was found between the mean monthly saturation deficiency measured at 9 a.m. and the evaporation from the evaporimeter. For the twelve mean monthly values for twelve Australian evaporimeter stations the correlation coefficient has been found to be 0.972.

It is possible therefore to use saturation deficiency as an index of evaporating power, or to use the evaporation records as such in establishing factors which will give a more perfect measure of the efficiency of the rainfall. The relationship also enables estimates of evaporation to be made for stations where no evaporimeter is available. The most useful factors so far established are the ratios of rainfall to evaporation or of rainfall to saturation deficiency. In their annual values the first of these ratios was first suggested by Transeau¹ and the second by Meyer². In our work both these measures have been found to be of considerable value. In their annual form they enable the climates of continental areas to be compared allowing for the effect of latitude, altitude, and distance from the ocean in relation to the effects of temperature and humidity on the efficiency of the rainfall. In this way maps of the Meyer ratio have been prepared for Australia, India and Nigeria, thus enabling comparisons to be made on a more rational basis than is afforded by rainfall alone.

It has been found that the monthly values of these ratios form a valuable guide to climatic conditions throughout the year, and permit of such measures of agricultural usefulness to be calculated with precision as the length of the growing season and the amount of influential rain.

In connection with the study of the ecology of such insects as the lucerne flea and the plague grasshopper, the activities of which depend so much on soil moisture conditions, the ratio of rainfall to evaporation has been investigated. The distribution of the monthly ratios of 1 and of 0.5 have been established for Australia, that is the areas have been mapped where in each month the rainfall and evaporation are equal or where evaporation is twice the rainfall. The latter ratio

¹ E. N. Transeau: *Amer. Nat.*, 39, 875, 1905.

² A. Meyer: *Chem. der Erde.*, p. 209, 1926.

has been found to be of value in determining the limiting soil moisture conditions for such insects as those mentioned above.

For the maintenance of soil moisture at or above the wilting point of plants a monthly ratio of rainfall to saturation deficiency of 5 affords tentatively a limiting value for the Waite Institute soil, and it is evidently possible to establish other values for the optimum soil moisture conditions for plants and for the onset of drainage.

In these terms it has proved possible to establish the probable limiting distribution of the lucerne flea and to establish general bioclimatic zones for Australia as a whole.

These bioclimatic zones are determined by the number of months for which the ratio of rainfall to evaporation is greater than 0.5 and by the mean annual temperature. A combination of the temperature zones: hot, warm temperate, and cool temperate with nine subdivisions with the five moisture zones: desert, arid, semi-arid, semi-humid, and humid, enables Australia to be subdivided into 29 separate climatic regions, with further subdivision possible in terms of the seasonal distribution of rainfall.

The climatic control of the Australian deserts has been discussed in terms of the monthly ratios of rainfall to saturation deficit. Where these values do not exceed four or five for any of the twelve months of the year, the soil moisture throughout the year is maintained below the wilting point of plants except immediately after rain for short periods or in special habitats. For the first time possibly a logical and reasonable definition of a desert climate becomes possible.

It must not be supposed that these ratios represent the final solution of the problem of measuring rainfall efficiency, but they appear to be the most efficient so far established, and will only be modified through a direct experimental attack on the problem.

Waite Arboretum

Under the deed of gift of the late Mr. Peter Waite whereby the Urrbrae Estate was transferred to the University, it was provided that portion of the area containing 67 acres should be held in perpetuity as a park. It was further provided that the Council of the University may set apart a portion, not exceeding 15 acres,



Acacia decurrens (Black Wattle), 1936. Tree No. 80. Planted 1928.

for the purposes of a sports ground for graduates and undergraduates of the University.

To give effect to this the University Council decided that the best means of carrying out the terms of the gift would be to establish on this area an arboretum in which trees and shrubs should be grown as specimen trees to demonstrate their value for shelter and ornamental purposes.



Angophora intermedia (Apple Myrtle), 1936. Tree No. 162. Planted 1928.

On this area 1,020 trees have been planted comprising 67 families, 180 genera and 367 species. Most of these trees were planted during the period 1928-30. A classified list of trees and shrubs was included in the Report for 1925-32.

Considerable variations in the growth of the various species have been ob-

served. Of the Australian species the Acacias in general have made rapid initial growth, and within five to six years have formed trees 10 to 14 feet high. Of the Myrtaceae, the Angophoras, and certain species of Eucalypts, e.g. *E. citriodora*



Virgilia capensis (Cape Virgilia), 1936. Tree No. 307. Planted 1928.

and *E. Smithii*, have grown very rapidly, whilst another species, *E. ficifolia*, has grown comparatively slowly. The introduced deciduous trees such as various species of elm, ash, poplar and oak, appear to do well in the Adelaide environment, as also do the various species of cypress.

A representative selection of about 150 trees is being measured periodically to determine the increased rate of growth of the species as measured by height, girth, and canopy cover. A random selection of 20 species given in the table below indicates the alteration in height and girth of the various species in one year.

Comparative Height and Girth of Trees in 1934 and 1935.

No. and Name of Tree.	Date Planted.	Height.		Circumference of trunk 2 ft. from soil.	
		May, 1934. inches.	May, 1935. inches.	May, 1934. inches.	May, 1935. inches.
57 <i>Acacia dealbata</i> (Silver Wattle)	1930	69	165	1.5	4.5
517 <i>Agathis robusta</i> (Kauri Pine)	1928	90	99	3.25	5.75
529 <i>Araucaria Bidwillii</i> (Bunya Bunya Pine)	1928	66	75	4.0	5.0
675 <i>Baloghia lucida</i> (Norfolk Island Bloodwood)	1929	90	102	2.25	3.5
10 <i>Brachychiton populneo acerifolius</i> (Wentworth Flame Tree)	1928	53	60	4.5	4.5
244 <i>Brachychiton rupestris</i> (Bottle Tree)	1928	44	48	1.5	2.25
806 <i>Cordyline terminalis</i>	1930	76	87	1.5	2.5
264 <i>Elaeodendron australe</i>	1928	104	108	3.0	5.5
194 <i>Eucalyptus ficifolia</i> (Red-flowering Gum)	1928	81	90	4.5	6.5
202 <i>Eugenia Smithii</i> (Lillypilly)	1928	78	90	4.75	5.5
925 <i>Flindersia australis</i> (Crow's Ash)	1929	132	144	4.75	7.0
106 <i>Gmelina Leichhardtii</i> (Queensland Beech)	1931	54	72	3.25	3.25
221 <i>Hakea laurina</i> (Pincushion Flower)	1928	100	108	8.75	10.0
152 <i>Lagunaria Patersonii</i> (Cow-itch Tree)	1930	114	120	5.5	7.25
926 <i>Macadamia ternifolia</i> (Queensland Nut)	1929	93	111	1.5	2.75
179 <i>Melaleuca gibbosa</i> (Slender Honey-myrtle)	1931	108	114	4.5	7.5
785 <i>Metrosideros tomentosa</i> (New Zealand Christmas Tree)	1929	90	99	2.25	3.5
538 <i>Podocarpus elata</i> (She or Brown Pine)	1928	102	111	3.25	4.75
554 <i>Sequoia sempervirens</i> (Redwood)	1928	54	66	3.5	5.0
271 <i>Sideroxylon australe</i> (Scrub-crab)	1929	76	93	2.25	3.5

Reports on Special Topics

Investigations on Plant Virus Diseases

At the time of the establishment of the Waite Institute a disease of tomatoes first described from Victoria by Brittlebank (1919) and named *Tomato Spotted Wilt* by him, had become economically important in South Australia and the eastern States. With the co-operation of the Council for Scientific and Industrial Research an investigation of the disease was begun at this Institute under the direction and leadership of Mr. Geoffrey Samuel. The main results of these investigations up to the end of 1932 have been outlined in a previous Report (1) and need be only briefly summarized here.

In 1926 when the work was begun very little was known about the disease, chiefly because no visible organism could be shown to be responsible for it. The disease was soon shown to be due to a virus which was transmitted from plant to plant by two insects, *Frankliniella insularis* and *Thrips tabaci*, the former being chiefly responsible for spreading the disease in this State. The habits and other characteristics of the insect were investigated, and an interesting finding was that an adult insect was incapable of infecting a plant unless it had fed on diseased plants when in the larval stage. Further work in co-operation with the Department of Entomology of this Institute was directed to a study of the bionomics of *Frankliniella*. Following the discovery of the insect vector a survey was made of the plants likely to act as natural reservoirs of the virus. The host range was found to be very wide, embracing a large number of widely-grown ornamental garden plants as well as economic crops and weeds. Tobacco plants growing in commercial plantations have also been shown to be, at times, seriously affected by this virus.

Attempts to control the disease were directed along two main lines. First, an attempt was made to control the insect carrier by means of insecticidal and repellent dusts. These experiments were not successful, however, and further developments along this line must await advances by entomologists in the control of this type of insect.

Secondly, a search was made for a resistant variety. No commercial variety of tomato was found to have any useful measure of resistance, but the wild, currant tomato, *Lycopersicum pimpinellifolium*, was found to be highly resistant in the field. Attempts to obtain a resistant variety of commercial value by crossing the currant tomato with commercial varieties have, however, proved unsuccessful. During the course of these investigations valuable methods of mechanical trans-

mission of the disease and for the estimation of relative concentrations of active virus in the juices expressed from diseased plants, were developed.

The third possible means of control, namely the eradication or reduction of other plants which are known to act as reservoirs of the virus, is ruled out on account of the wide host range. Although the removal of such plants from the immediate neighbourhood of the tomato crop, the removal and destruction of diseased tomato plants and the use of repellent dusts may be of some value, the measure of control obtainable by these means was so small that it was felt that a fundamental investigation of the virus itself with a view to obtaining some knowledge of its nature and properties was necessary before much further progress could be made. As a result of some preliminary work the co-operation of a chemist from the Department of Agricultural Chemistry was obtained. The results of this co-operative work proved to be very interesting and, as they showed this aspect of the problem to be chiefly a chemical one, the work has been carried on by this department since the departure of Mr. Samuel in March, 1934, to take up an appointment at Rothamsted, England.

Since the virus of tomato spotted wilt was found to be one of the most unstable viruses known, a second virus, that responsible for tobacco mosaic disease, was chosen for parallel studies because it is particularly stable and resistant to those agencies which inactivate tomato spotted wilt virus. The study of these two very different viruses, side by side, is therefore likely to give a better perspective of the whole problem and to indicate lines of approach in the study of other viruses.

Estimation of Relative Virus Concentrations.

At the outset it was realized that more exact methods of estimating relative concentrations of active virus were required. The first efforts were therefore directed towards further improvements in the primary lesion method of estimating such concentrations and towards the evaluation of the possibilities and limitations of the method. Since the bulk of the work was concerned with the effect of various chemical treatments on the virus, *in vitro*, the tests were arranged in such a way that effects on the virus itself could be distinguished from effects on the inoculated plants. It was found that the concentration of electrolyte and the relative acidity (pH value) of the inocula as well as details of technique had to be standardized in order to obtain reproducible results. The effects of variation in susceptibility of test plants were reduced by making use of the Latin square and other arrangements, combined with statistical analyses of the data (2).

Environmental conditions, such as temperature and light, to which the test plants were exposed both before (2) and after (3 and 4) inoculation were found to affect the number of primary lesions produced by one and the same inoculum, and these factors have either been standardized or, where this has not been possible, the magnitude of the effects has been evaluated in order to take it into account when interpreting the data. As a result of this work it is now possible to determine

the relative concentrations of active virus in inocula with a degree of accuracy which may be considered high for a biological method (5).

Because of the short *in vitro* "life" of tomato spotted wilt (about six hours) experiments with this virus have been made with unpurified samples of infective juice. This procedure introduces complications because other constituents of the juice react with the virus. Experiments have therefore been carried out to find the best conditions for maintaining suspensions of the virus in an active state for periods long enough to enable attempts at purification to be made. By bubbling purified hydrogen through suspensions protected by cystein and maintained at a low temperature, suspensions of this virus have been kept for six days without any falling-off in activity. Similarly prepared suspensions stored in sealed tubes were still active 35 days after preparation but there was a falling-off in activity over this period. The experiments are still in progress, and the problem of separating the virus from other constituents of the juice does not now appear as hopeless as it did previously.

Since under ordinary conditions both the susceptibility of test plants and the concentration of active virus in the hosts used as source vary from experiment to experiment, inter-comparison of the results of experiments carried out at different times would be less difficult if a standard inoculum of constant virus concentration were available. It is well-known that tobacco mosaic virus will remain active outside the living host for some years. Attempts to prepare suspensions of this virus which will maintain their activity unimpaired over long periods have been successful. As far as can be judged by the primary lesion method, suspensions of the purified virus stored in a refrigerator at about 0.5° C. are still as active as they were 16 months ago, and one stock suspension has served as the source of virus for *in vitro* tests over the whole period. Attempts to preserve purified virus preparations in the dry state met with only limited success. Virus isoelectrically precipitated in August, 1934, and dried in a vacuum desiccator at room temperature was active when tested 15 and 22 days after preparation and other samples have remained active for several months but gradually lost their activity with time. Desiccation apparently renders the virus inactive.

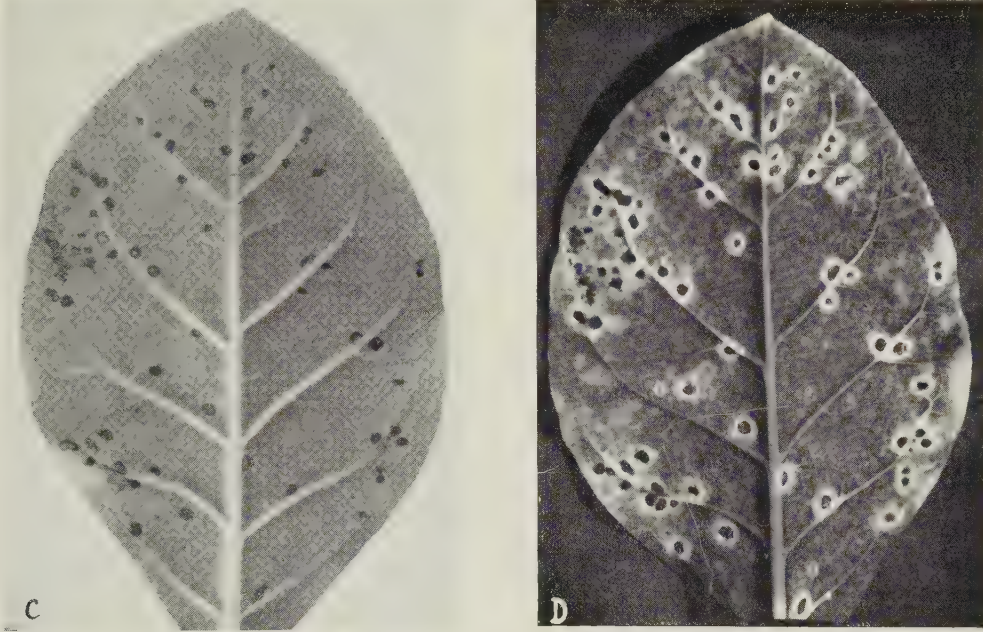
Some Properties of the Viruses of Tomato Spotted Wilt and Tobacco Mosaic.

Tomato Spotted Wilt.

Experiments conducted with suspensions of this virus showed that it was speedily inactivated in relatively weak acid media, that it remained active over the pH range 6 to 9 and was inactivated in suspensions more alkaline than pH 9 (6). Treatment with a number of mild oxidizing agents and reducing agents revealed the virus to be readily inactivated by dilute solutions of oxidizing agents which induce in the suspensions an oxidation-reduction potential of +0.2 volt or higher at pH 7 (7). Normally suspensions of the virus become inactive after about six hours' exposure to air, but the addition of suitable reducing agents has

resulted in suspensions maintaining their original activity for much longer periods, although eventually these suspensions also lose their activity.

An autoxidizable substance (oxygen carrier) and a catalyst which catalyzes the oxidation of certain phenolic substances by atmospheric oxygen were found to be present in the juice expressed from leaves of diseased plants. The short life of



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Photographs of the underside of a leaf of *Nicotiana tabacum* showing primary lesions produced by the virus of tomato spotted wilt.

C. Photographed in daylight.

D. Showing the fluorescent haloes surrounding the lesions when photographed by filtered ultra-violet light. The incident light was cut off by interposing an aesculine filter between the leaf and the camera lens so that the leaf was photographed by the light of its own fluorescence.

the virus in unprotected suspensions is explained by the following reactions. Under the influence of the catalyst the autoxidizable substance is oxidized by atmospheric oxygen and then inactivates the virus by an oxidation process (7, 8).

A soluble fluorescent substance has been shown to be produced in relatively large amounts in the neighbourhood of necrotic primary and secondary lesions on tobacco and other plants (9). The nature of this substance and the significance of the phenomenon are being followed up.

Tobacco Mosaic Virus.

This virus was found to be very resistant to acid conditions but was very easily inactivated in weakly alkaline solutions (6). It remains active over the pH range 2 to about 8 but is inactivated above pH 8 and below pH 2. Over the critical pH range on the alkaline side the activity of the virus falls to a certain value and then remains constant, indicating that a definite proportion of the virus has been inactivated. From further work (10) it appears that the fall in virus activity is associated with the neutralization of an acid group or groups.

Although the virus remains active between pH values of 3 and 4 it precipitates from solution over this range, and the point of maximum precipitation or isoelectric point is at pH 3.4 (3, 11). At this pH value practically the whole of the virus in a sample of infective juice may be precipitated, and the product appears to be homogeneous. Chemical tests and the nitrogen content of the virus precipitate showed it to be a protein or protein complex (11).

Some Observations on the Probable Nature of the Viruses.

As a result of work carried out in the United States, in England and at this Institute, it is now fairly evident that the virus responsible for ordinary tobacco mosaic is essentially protein in nature. Little is as yet known about the make-up of this protein, whether, for example, the activity resides in the protein proper or whether this latter is conjugated with some prosthetic group or groups. On the available evidence and from general considerations the latter would appear to be more likely. Under suitable conditions the virus particles link up into long, thin, flexible needles or threads. These show double refraction with straight extinction but have the properties of the mesomorphic state and are easily dispersed to sub-microscopic dimensions. At the temperature of the thermal inactivation point of the virus the long flexible mesomorphic fibres collapse and change abruptly to a clumped condition.

The virus of tomato spotted wilt has not yet been separated from other constituents of the plant juice and presents a much more difficult problem. However, its properties and general behaviour lead to the working hypothesis that this virus is enzymic in nature, being active as a pathogen in its reduced state. Its comparatively large size places it in a different structural category from that of the smaller mosaic virus, and its chemically reactive groups are very different in nature.

Viewing the plant viruses as a class and taking into account the property possessed by them in common with other viruses, of being able to multiply in living cells, and their wide range in size, the most logical picture of them appears to be that of a class of complex organic structures built on a protein base with a large number and variety of active prosthetic groups, these latter entering into the biochemical reactions through which the viruses become evident and which are at

the same time concerned with processes which we have come to associate with life and living. This picture is essentially similar to that of Alcock's "living molecules"* and in the present state of our knowledge seems to fit the facts best and to form a logical conception of this group of entities.

The Outlook from the Point of View of Control Measures (T.S.W.).

The work at present in progress has as its immediate object the obtaining of a better understanding of viruses themselves and of their properties. However, it is worth while even at this early stage to review the position from the point of view of control measures.

It is evident that this virus spreads through the plant by way of the vascular bundles so that once a plant has become systemically infected there would appear to be little chance of saving it. Measures must therefore aim at preventing infection from becoming systemic.

The control of insect vectors and the breeding of resistant varieties, although so far unsuccessful, have still their possibilities and may be left to the entomologist and to the geneticist. Any information which might be obtained on the factors, biochemical or structural, which determine resistance would open up new possibilities to the plant breeder.

Another possible means of control has been opened up by the chemical work, namely the possibility of introducing into the plant by spraying or other means, chemicals which will inactivate the virus at the site of entry before it has a chance to spread to the rest of the plant. In the case of tomato spotted wilt the presence of suitable oxidizing systems would be expected to have this effect but the problem is not a simple one. One difficulty would be to introduce sufficient of such substances into the plant to prevent the spread of any virus introduced by insects, without at the same time causing injury to the plant. Oxidizing agents which would be capable of inactivating the virus would be converted to the reduced state by normal constituents of the plant cells and thus rendered inoperative. Some preliminary tests have shown that spraying with a few simple oxidizing agents known to inactivate the virus *in vitro* does not protect the plant against the disease. There is, however, the possibility that some inactivant may be found which will remain unaltered in the normal plant. Finally, when more is known about the properties of the virus and its mode of action in the plant, this knowledge will be of assistance not only in a search for resistant varieties but may indicate the basis of methods aimed at increasing or building-up the resistance of susceptible varieties by nutrition or other means.

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R. J. BEST.

The Water Requirements of Pasture Plants

Under conditions of limited seasonal rainfall, the persistence of pasture species frequently depends upon their capacity to survive periodic drought; and the amount of production attainable depends largely on the economic utilization of the available water supply.

The quantity of water required by plants for the production of a given amount of dry matter is readily measurable under controlled experimental conditions, and is conveniently expressed as the transpiration ratio. This is the ratio of the weight of water lost by transpiration to the weight of dry matter produced exclusive of roots. Quite apart from questions of drought survival and persistence under grazing, the determination of the quantities of water required by pasture plants for production purposes, and the factors influencing transpiration are of considerable economic importance.

Over the major portion of the principal grazing areas of Southern Australia, conditions of winter rainfall and summer drought obtain. The climate is essentially of the Mediterranean type and growth from pastures occurs mainly in the autumn, winter and spring months. The summer period of aridity is characterized by low rainfall, intense heat and high evaporation, and the extent of the arid period varies according to location and to season. The establishment of permanent pastures in such areas presents greater difficulties than under more temperate conditions, such as occur in Western Europe and New Zealand. In view of the particular importance of rainfall as a factor limiting production in the Australian environment, the transpiration ratio of a selected range of pasture plants including the more important native and exotic species, has been determined at the Waite Institute, together with the factors affecting the water requirement of such species.

1. *Water Requirement of Pasture Species.*

The water requirement of nineteen pasture species was determined during the season 1931. The technique for this work has already been described (Richardson, Trumble and Shapter, 1931). The transpiration ratio of the species concerned was found to vary considerably, as is shown in the following table:

A. Species adapted to low rainfall conditions.

1. Early maturing exotic annuals:

Species.	Transpiration Ratio.	Standard Error.
Barley	234	5.0
<i>Medicago denticulata</i>	326	8.1
<i>Phalaris minor</i>	357	5.7
<i>Hordeum murinum</i>	363	5.1
<i>Erodium botrys</i>	403	9.1

2. Indigenous perennials:

<i>Atriplex semibaccatum</i>	377	12.5
<i>Atriplex vesicarium</i>	400	9.1
<i>Danthonia semiannularis</i>	414	8.1
<i>Danthonia Duttoniana</i>	414	6.8

B. Species adapted to moderate or high rainfall conditions.

1. Exotic annuals:

<i>Lolium subulatum</i>	464	25.5
<i>Lolium multiflorum</i>	468	11.9
<i>Trifolium subterraneum</i>	508	7.4

2. Exotic perennials:

<i>Lolium perenne</i>	488	12.6
<i>Trifolium repens</i>	500	8.8
<i>Plantago lanceolata</i>	512	10.6
<i>Phalaris tuberosa</i>	512	12.7
<i>Holcus lanatus</i>	557	13.2
<i>Trifolium fragiferum</i>	575	21.9
<i>Dactylis glomerata</i>	581	19.4

2. Effect of Environment on the Water Requirement of Pasture Species.

The water requirement and the march of transpiration in relation to environmental factors were determined for a period of seven seasons with two typical pasture species, *Lolium subulatum*, *Trifolium subterraneum*, and a typical graminaceous annual, barley.

The transpiration ratio for these three species over a seven-year period is summarized in the following table:

Seasonal Variation in the Transpiration Ratio of Lolium subulatum, Trifolium subterraneum and Cape Barley, for seven years, 1925-31, at Adelaide.

Season.	<i>Lolium subulatum.</i>	<i>Trifolium subterraneum.</i>	Barley.	Seasonal Mean.
1925	352	478	269	366
1926	284	478	249	337
1927	494	653	501	549
1928	452	482	428	449
1929	451	494	374	439
1930	497	509	351	452
1931	464	508	233	402
Mean	428	514	344	428
S.E. (%)	6.95	4.79	10.52	6.00

The transpiration ratios for the three species show wide seasonal fluctuations. These fluctuations were found to be due to the seasonal variations in the intensity of the environmental conditions during the period of active growth of the plant.

Transpiration losses are dependent on two major factors; (1) the area of green transpiring surface of the plant available, and (2) the intensity of the environmental factors, i.e. mean air temperature, saturation deficit of the air, and wind movements.

The area of green transpiring surface of a barley plant increases (Richardson and Trumble, 1928) to a maximum at, or slightly after, the flowering stage, after which it gradually declines. In an unchanging environment, therefore, maximum transpiration would coincide with maximum green leaf area.

With plants growing under winter rainfall conditions, however, the period of maximum transpiration occurs at a later stage than that of the maximum production of green leaf area, owing to the fact that mean air temperature and saturation deficit of the air increase rapidly as the season advances towards the summer. Moreover, the transpiration rate is often subject to great temporary acceleration due to the occurrence of hot northerly winds during October and November.

Transpiration is closely correlated during the growing period with the rate of evaporation from a free water surface, which in its turn may be regarded as the summation of the effects of air temperature, saturation deficit of the air, and wind movements. Conditions leading to a high evaporation rate during the critical period of maximum transpiration will inevitably cause heavy transpirational losses without a corresponding increase in dry matter production, with the result that the water cost of producing dry matter will be high. As the atmospheric conditions affecting evaporation vary from season to season, the transpiration ratio will necessarily vary accordingly.

The highest values for all plants were recorded in 1927, whilst the lowest were recorded in 1925 and 1926. The high mean values for the transpiration ratio in 1927 compared with 1926 and 1925, were due mainly to the increased intensity of the environmental factors during the critical period of maximum growth and transpiration from mid-September to the end of October in 1927.

The March of Transpiration in Relation to Environmental Factors.

During a period of active transpiration (October 31 to November 2, 1928) records of the transpiration losses for rye grass (*Lolium subulatum*), subterranean clover (*Trifolium subteranneum*), trailing saltbush (*Atriplex semibaccatum*) and Sepoy wheat (*Triticum sativum*) were taken at two-hourly intervals in a glass pot culture house for three consecutive days and nights to compare the march of transpiration with that of the march of air temperature, saturation deficit of the air, and evaporation from a free water surface.

Transpiration was measured by the loss in weight from plants growing actively in glazed earthenware pots with 20 kilograms of soil, maintained at approximately 55 per cent. of the water-holding capacity of the soil. The transpiration loss for each species was obtained from the mean of three pots and was recorded in grams per two-hour period by weighing on scales sensitive to ten

grams with a load of 40 kilos. The losses in weight by transpiration were made good by adding water at the end of each day of observation.

Wet bulb depression was measured by the mean difference in temperature (in degrees Fahrenheit) between the wet and dry bulb thermometer at the commencement, middle and end of each two-hourly period.



Transpiration tests with various pasture plants, Waite Institute.

Evaporation was measured by the mean loss in weight of water from four blackened circular copper pans, 45 centimeters in diameter and 4 centimeters high, in which the water level was maintained at 2.0 centimeters in depth.

The transpiration losses for successive two-hour periods for three consecutive days during periods of intense transpiration for each of the four types of plants are summarized in the following table, together with losses by evaporation from a free water surface during the same period.

Mean Transpiration losses from Sepoy Wheat, Rye-grass (Lolium subulatum), Subterranean Clover (Trifolium subterraneum) and Saltbush (Atriplex semibaccatum) in two-hourly periods for three days compared with losses by evaporation from a free water surface.

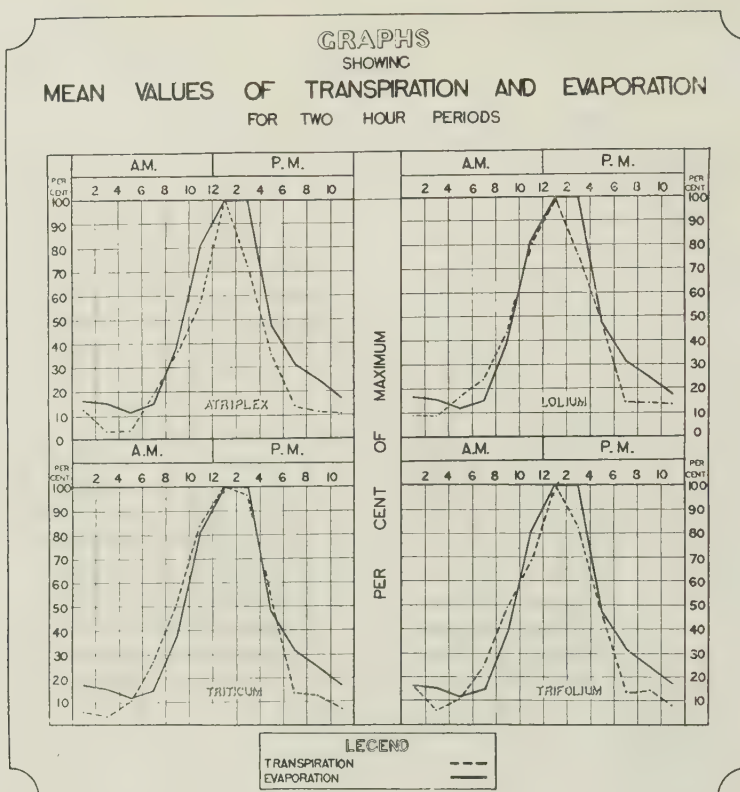
Hour.	Sepoy Wheat.	<i>Lolium</i>	<i>Trifolium</i>	<i>Atriplex</i>	Evaporation.
a.m.	Mean loss per	subulatum.	subterraneum.	semibaccatum.	Actual loss
	pot (grams).	Mean loss per	Mean loss per	Mean loss per	(grams).
		pot (grams).	pot (grams).	pot (grams).	
12- 2	13.8	26.6	40.0	31.1	31
2- 4	8.6	26.6	15.0	7.6	30
4- 6	28.7	44.8	26.6	8.8	22
6- 8	72.6	66.6	60.0	45.7	28
8-10	133.8	118.4	122.0	94.3	76
10-12	221.6	220.8	168.3	139.3	156
p.m.					
12- 2	266.6	274.1	245.8	242.1	193
2- 4	256.0	210.0	202.4	172.6	193
4- 6	140.5	135.0	115.8	86.5	91
6- 8	36.5	38.8	33.2	32.2	60
8-10	33.3	38.4	36.6	27.7	48
10-12	18.7	38.3	20.0	25.5	33

Transpiration losses were continuous throughout the day and night, but the rate of transpiration varied considerably. With all crops the minimum losses occurred during the period 2-4 a.m. Transpiration increased rapidly from 8 a.m. till noon, and reached a maximum during the period 12-2 p.m. The transpiration rate remained at a high level till 4 p.m., after which it declined rapidly till 8 p.m., and very gradually till 4 a.m.

Transpiration was found to be more active in the afternoon than in the forenoon. Of the total transpiration losses for the four crops tested, 60 per cent. of the loss was recorded during the period from noon to midnight, and 40 per cent. of the loss from midnight to noon. A similar ratio of losses was observed for the period noon to 6 p.m., and from 6 a.m. to noon.

The march of transpiration for each species in relation to evaporation is shown in the accompanying graph. The data for the various plants have been reduced to a uniform basis by plotting the mean transpiration losses in two-hourly periods expressed as a percentage of the maximum against the percentage of the maximum range. The graph of the bi-hourly losses by evaporation from a free water surface follows very closely the graph of the corresponding losses by transpiration from each crop. With *Atriplex*, *Lolium* and *Trifolium*, transpiration falls in advance of evaporation, though with wheat the transpiration graph closely follows that of evaporation.

The correlation coefficients between transpiration and evaporation were calculated from the individual bi-hourly observations of losses by transpiration from



Bi-hourly march of transpiration in relation to evaporation for *Atriplex*, *Lolium*, *Trifolium* and wheat.

each crop, and the corresponding bi-hourly losses by evaporation for the three-day period. The results are summarized for each species in the following table:

Correlation between Transpiration and Evaporation with Wheat, Clover, Ryegrass and Saltbush.

Species.	Correlation coefficient.
Wheat	.955
Subterranean clover	.932
Wimmera rye-grass	.912
Saltbush	.909

$P < .01$

As the daily march of transpiration shows a high degree of correlation with the rate of evaporation from a free water surface during the period when the plant is growing actively, and as evaporation may be regarded as the resultant of the effects of air temperature, saturation deficit and wind movement, it follows that

the evaporation rate from a free water surface during the period of active growth of a pasture plant will be a good index of the probable water cost of producing dry matter from that particular species.

3. Water Requirement at Different Growth Stages.

The dry matter production and transpiration efficiency of four pasture species and barley have been determined at various stages throughout their growth period. *Lolium subulatum* and *Trifolium subterraneum* in 1927, *Erodium botrys* in 1928, *Phalaris tuberosa* in 1930, representing an annual grass, annual clover, annual miscellaneous herb and a perennial grass of a winter rainfall region, were the species investigated. The results obtained are summarized in the following table:

Transpiration Ratio of Pasture Plants at Varying Stages of Growth.

Harvest.	Stage.	Barley.	<i>Lolium subulatum.</i>	<i>Trifolium subterraneum.</i>	<i>Erodium botrys.</i>	<i>Phalaris tuberosa.</i>
1	Tillering	229	215	287	188	296
2	Advanced tillering	230	224	364	—	342
3	Flowering	257	283	435	255	414
4	Past flowering	262	370	532	—	510
5	Maturity	270	494	653	375	619

With each species the transpiration ratio significantly increased as the plant advanced towards maturity. The increase in the transpiration ratio and the corresponding fall in the transpiration efficiency as the plant advanced its growth stage may be explained by the differences in the relative rates of carbon assimilation and transpiration throughout the growth period of the plant.

During the early growth stages of a pasture plant in a region of winter rainfall, and especially during the winter months, mean air temperatures are low and atmospheric humidity is high. After the cessation of the winter rains, mean air temperatures and the saturation deficit of the air increase rapidly, and the average evaporation at Adelaide in the spring months, when the flush of growth takes place, is approximately four times as great as the average evaporation rate during winter.

After the flowering stage is reached, the area of green transpiring surface diminishes. With the fall in green leaf area there is a corresponding fall in the rate of production of dry matter. Transpiration, however, remains very active because the reduction in green leaf area is more than compensated for by the marked rise of mean air temperature and saturation deficit of the air, i.e. in the evaporating power of the air.

Transpiration proceeds more slowly than carbon assimilation in the early stages, keeps pace with carbon assimilation at the flowering stage, and greatly

exceeds it in the final growth stage. As a consequence the transpiration ratio of the plant increases from tillering to maturity.

From these considerations it would appear that the judicious control of the growth stage of pasture plants by rotational grazing might result in the more economical production of dry matter, expressed in terms of water cost, apart from other obvious advantages such as high protein and mineral content of the herbage.

4. Effect of Defoliation on the Transpiration Ratio.

In the previous section it was shown that the transpiration ratio was lowest in the early stages of growth and that it invariably increased as the plant advanced towards maturity, and that the final stages of growth were characterized by considerable losses by transpiration without corresponding increases in dry matter production.

Under rotational grazing conditions the accumulation of somewhat mature but actively transpiring leaves would tend to be reduced, and the pasture maintained on the whole at an early growth stage. Transpiration might therefore be expected to be less from grazed than from ungrazed herbage. On the other hand dry matter production would tend to be retarded and thus exercise an opposite effect on the transpiration ratio.

The effect of defoliation on the production of dry matter and the transpiration ratio of a typical pasture plant—perennial rye-grass—was determined under pot culture conditions in 1932. Cuttings to 1 inch above soil level were made at intervals of 3, 4, 5, 6, 8, 12 and 24 weeks. The results are summarized in the following table:

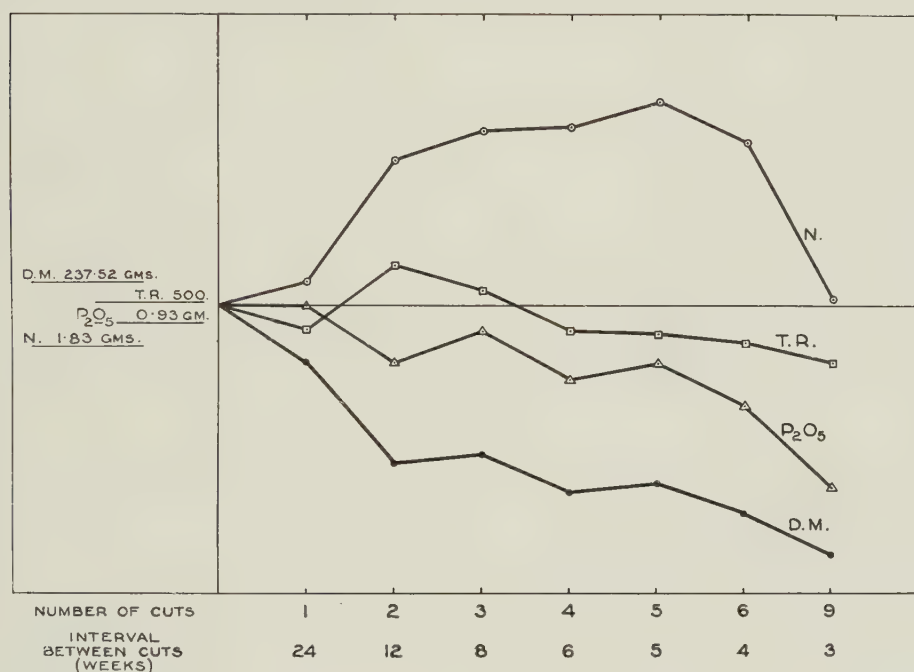
Effect of Defoliation on Rye-grass.

No. of cuts during season.	Interval in weeks.	Dry matter produced (grams).	Transpiration Ratio.
1	—	260·96	462
2	24	240·36*	431*
3	12	127·24	497*
4	8	137·22	442*
5	6	102·32	384
6	5	104·45	377
7	4	83·03	369
9	3	43·31	315

* Difference compared with one cut not significant.

The effect of defoliation on the transpiration ratio appears to depend on the capacity of the species to recover rapidly and produce new herbage soon after defoliation, and on the environmental conditions following defoliation. The severity of defoliation by cutting would of course be much greater and more complete than that following upon grazing—unless the latter was so heavy and intense as to remove practically all herbage to 1 inch above soil level.

It is of interest to note that increased defoliation did not in any case increase the transpiration ratio significantly; either no significant change or a reduction ranging from 10 to 30 per cent. of the value of a single cut was obtained. When, however, the transpiration results are related to the absorption of nitrogen and phosphoric acid, the effect of the cutting becomes more significant. Increased frequency of cutting up to the limit of 3-weekly defoliation resulted in significantly higher quantities of nitrogen and phosphoric acid being absorbed per unit of water transpired. The greatest yield of nitrogen was, however, obtained with defoliations at intervals of five weeks.



Graph showing effect of differential cutting treatment on the yields of dry matter, nitrogen and phosphoric acid and on the transpiration ratio of perennial ryegrass (*Lolium perenne*), Waite Institute.

Investigations on the effect of defoliation with *Phalaris tuberosa* (Richardson, Trumble and Shapter, 1932) showed that taking into consideration yield of dry matter, yield of nutrients and conservation of water in relation to nutrients and the permanence of the plant in a winter rainfall environment, a system of three defoliations applied to *Phalaris tuberosa* would probably give optimum results. The practical application appears to lie in comparatively frequent but not drastic grazing during the early vegetative period followed by more intensive grazing in spring and early summer, or alternatively an early cutting of the pasture for conserva-

tion as silage. Late cutting as hay is less attractive an alternative because the nutritive value of the hay will be low and some interference with the accumulation of basal reserves is likely to occur.

5. *Effect of Fertilizers on Water Requirement.*

Australian soils as a whole show a marked deficiency in available phosphoric acid. Throughout the cereal belt the application of soluble phosphates is regarded as essential to economic crop production, and in areas of higher rainfall the application of soluble phosphate is equally necessary for sown pastures.

The nitrogen content of Australian soils compared with European standards is low. Prescott (1931) gives the nitrogen content of a number of soils from thirty localities in Eastern Australia, and records that 102 soils show a nitrogen content below 0.05 per cent. Field experiments conducted over a series of eight years at the Waite Institute have shown that while applications of nitrogen gave little or no response on cereals when sown on well prepared bare fallow, there was a substantial and profitable response when these cereals were sown on stubble land. As the demands of a pasture crop for nitrogen are considerable, satisfactory growth can be maintained if the nitrogen level of the soil is maintained either by leguminous plants in the pasture, or by the use of nitrogenous fertilizers.

In view of the prevalence of phosphate deficiency in Australian soils and pastures, the influence of phosphates on the water requirement of pasture species has formed a feature of the water requirement investigations.

Soluble Phosphates.

The effect of superphosphate on the transpiration ratio of six typical pasture species (*Danthonia*, *Atriplex*, *Trifolium* (two species), *Erodium* and *Lolium*) on Waite Institute soil showed an average reduction of 16.7 per cent., with a range of 8.8 per cent. in the case of *Trifolium subterraneum* to 30.8 per cent. with *Erodium botrys*. The application of superphosphate in all cases substantially increased dry matter production and root development, and resulted in a substantial reduction in the water cost of producing dry matter. These effects were observed throughout the entire growth of the pasture plants, but were most marked during the early stages of growth.

The fact that the reduction in transpiration ratio due to the application of phosphate is particularly marked in the early stages indicates that the acceleration of maturity induced by the phosphate is not an important contributing cause, but that the increased phosphorus supply acts rather by increasing the efficiency of dry matter production in terms of water utilized, from the earliest stages of development.

The amount of water transpired by each species on soil treated with superphosphate was actually greater in all cases than by the plants grown on unfertilized soil. Manuring with superphosphate thus increases the amount of water

needed by the pasture plant. This is due to the increased development of the plant, and to a greater transpiring surface exposed to the atmosphere.

The application of soluble phosphate to a soil with low available phosphate enables assimilation to proceed at a more rapid rate without, however, a corresponding increase in the transpiration rate. The superphosphate greatly stimulates early growth and development of roots, tillers and leaves, and the plant with this early vigorous start continues to increase its dry matter in an economical manner throughout its period of growth. On the other hand, growth is retarded on the unfertilized soil, but transpiration, which is largely dependent on air temperature and saturation deficit, is continuous. The water cost of dry matter production is therefore higher on the unfertilized soil.

Nitrogen.

The effect of nitrogen was determined on a typical pasture plant—Wimmera rye-grass—in a series of pot cultures with soil obtained from a Waite Institute stubble field on which a heavy crop of oats was grown during the preceding year. One series of pot cultures was subjected to three cuts at intervals of approximately six weeks with and without nitrogenous fertilizers, and a second series was allowed to grow without defoliation until maturity when a single harvest was made. Each of the fertilized pots received 1.5 grams of sulphate of ammonia and 6 grams of nitrate of soda at the tillering stage. The results are summarized in the following table.

Effect of Nitrogen on Dry Matter Production and Water Requirement with Wimmera rye-grass (Lolium subulatum) on soil previously under Oats.

Treatment.	Cut once at maturity.				Cut three times.			
	Transpn. (kg.).	Dry Matter (gms.).	Transpn. Ratio.	Standard Error.	Transpn. (kg.).	Dry Matter (gms.).	Transpn. Ratio.	Standard Error.
No fertilizer	81.33	130.01	626	± 11	51.63	89.26	578	± 13
Nitrogen	91.84	197.71	465	± 6	53.66	112.34	478	± 14

The application of nitrogen produced a marked increase (52 per cent.) in the production of dry matter, especially where the plants were cut once at maturity, and the transpiration ratio was reduced by 26 per cent. with the application of nitrogen.

The application of nitrogen to rye-grass cut three times during its growth stage gave a total increase of 26 per cent. of dry matter as compared with a 52 per cent. increase when the pasture was allowed to proceed to maturity. The nitrogen and mineral content of the herbage cut thrice was, however, considerably higher for the produce of the three cuts treatment than for the single cut. The reduction in the water requirement under a three-cut system was 17 per cent. as compared with 26 per cent. from a single cut.

It is apparent that the effect of nitrogenous fertilizers with grass grown on soil which has insufficient nitrate for full production is to increase materially the total dry matter production, and to a lesser extent the actual amount of water transpired. As the increased amount of water transpired by the crop receiving the fertilizer is not commensurate with the very large increase in dry matter production, the water cost of producing the dry matter is substantially less with the crop receiving the fertilizer.

Nitrogen and Phosphorus on Mixed Associations of Grasses and Legumes.

Pastures are generally composed of mixed associations of grasses and legumes, and the influence of phosphate and nitrogen on the water requirement of a mixed association is therefore of practical importance.



Pot culture investigations, Waite Institute. Range showing the effect of increasing phosphate dressing, with uniform nitrogen treatment, on the growth and composition of *Phalaris tuberosa* and subterranean clover, 1934.

During 1935 an experiment was carried out in sand cultures to determine the effect of varying levels of soluble phosphate and nitrogen—other nutrients remaining constant—on the production and water requirement of Wimmera ryegrass and subterranean clover, grown separately and in association. The sand employed in this test was washed continuously for several weeks. Phosphorus was applied to all pots at the rate of 0.05 gram P_2O_5 as dihydrogen potassium phosphate (KH_2PO_4) and 0.05 gram nitrogen as potassium nitrate (KNO_3). These quantities of phosphorus and nitrogen were applied as a basal solution to each pot. Potassium was maintained constant in each pot by the adjustment of KCl application. In the following table P_2 and P_4 dressings refer to 0.25 gram and 0.50 gram

P_2O_5 respectively (added as KH_2PO_4); N_2 and N_4 refer to 1.0 gram nitrogen and 2.0 grams nitrogen respectively.

The effect of varying combinations of nitrogen and phosphorus on the grass, the clover, and the grass-clover mixture is summarized below.

Effect of Varying Phosphate and Nitrogen Applications on Transpiration Ratio.

Treatment	O	P_1	P_2	N_2	P_2N_2	P_4	N_4	P_2N_4	P_4N_1	P_4N_2	P_4N_4
(1) Total dry matter (gm.).											
Wimmera rye-grass	9.22	10.92	10.29	40.84	132.94	10.92	48.06	151.47	85.85	144.95	198.88
Subtn. clover	2.35	27.09	55.85	2.61	51.09	74.41	2.09	44.34	74.82	76.14	58.43
Wimmera rye-grass + sub. clover	9.89	24.64	51.40	38.05	129.77	64.87	35.00	152.67	92.41	134.93	195.00
(2) Proportion of clover in mixture (%).											
	2	56	81	0.4	2	84	0.1	2	29	6	1
(3) Transpiration ratio.											
Wimmera rye-grass	606	543	574	461	384	579	444	349	419	377	345
Subtn. clover	776	367	382	502	410	372	578	382	395	398	404
Wimmera rye-grass + sub. clover	559	430	419	505	410	444	494	361	429	406	351

All differences in dry matter production due to phosphorus or nitrogen treatment were significant except as between P_2 and P_4 on pure rye-grass, and as between N_2 and N_4 on pure clover.

It is of interest to note in the case of the mixtures (and this is true also of the treatments N_1 , P_1N_1 , P_1N_2 , P_2N_1 , and P_1N_4 which for simplification are not included in the above table) the tendency was towards either marked grass dominance or marked clover dominance with these two annuals.

Differences in the transpiration ratio due to nutrient treatment far outweighed those due to species. Thus the value for Wimmera rye-grass varied from 345 to 606, while for subterranean clover it varied from 367 to 776. The transpiration ratio of the mixed association varied from 351 to 559.

With rye-grass, nitrogen had a most marked effect in lowering the transpiration ratio; with subterranean clover, phosphate resulted in the greatest reduction in the transpiration ratio.

With the mixture of rye-grass and clover, liberal dressings of nitrogen in association with moderate to heavy dressings of phosphate caused a substantial reduction in the water requirement.

Ballard (1933) showed that the reduction in the transpiration ratio brought about by the application of nitrogen to Sudan grass was not due to an effect on the transpiration rate per unit weight of leaf, but to an effect on growth. In the case

of phosphates, Williams (1935) found that a decrease in the transpiration rate per unit weight of leaf occurred with oats and that there was in addition a reduction in the leaf weight ratio during part of the life cycle.

Manganese.

Samuel and Piper (1928) showed that on certain types of soil in South Australia there is a definite lack of available manganese in the soil and that this induces in oats the grey speck or manganese deficiency disease. One type of soil which was shown by them to be particularly deficient in manganese was a light calcareous soil from southern Yorke Peninsula.

During the autumn of 1931, a supply of manganese-deficient soil was secured from the farm of Mr. E. F. Filmer of Corny Point, South Australia. The soil selected was from a portion of the farm which during 1930 had, under field trials of the Department of Agriculture, shown a marked response to applications of manganese sulphate to barley.

Wimmera rye-grass (*Lolium subulatum*) was grown in a series of pots filled with Corny Point soil, and subjected to three manurial treatments: (1) No fertilizer, (2) Monocalcic phosphate, (3) Monocalcic phosphate and manganese sulphate. Pure monocalcic phosphate was applied at the rate of 1.25 grams per pot, and manganese sulphate at the rate of 0.5 gram per pot. The water-holding capacity of the soil was maintained at 45 per cent. throughout growth. The rye-grass was harvested at the flowering stage. The results are summarized in the following table:

Transpiration Ratio of Lolium subulatum grown with and without Manganese Sulphate on soil from Corny Point, South Australia.

Treatment.	Green Weight (grams).	Dry Weight (grams).	Transpiration (kilograms).	Transpiration Ratio and Standard Error.
No fertilizer	89.3	19.75	9.99	506 $\pm$ 19
Monocalcic Phosphate	122.3	25.48	12.22	480 $\pm$ 28
Monocalcic Phosphate and Manganese Sulphate	216.7	58.41	17.31	296 $\pm$ 8

The application of monocalcic phosphate to Corny Point soil increased the dry matter production of *Lolium* by 29 per cent. and the amount of water transpired by 22.0 per cent. The transpiration ratio of the monocalcic phosphate was 480, as compared with 506 for pots receiving no fertilizer.

Pots treated with manganese, however, showed a very substantial increase in the yield of dry matter and a significant and very marked reduction in the transpiration ratio. The yield of dry matter with manganese showed an increase of 129.2 per cent., as compared with the monocalcic phosphate pots, but the additional water used was only increased by 41.6 per cent. The transpiration ratio

was actually reduced by 39 per cent. on the manganese treated pots, as compared with the control pot of phosphate only.

It would appear, therefore, that with soils which are deficient in any nutrient necessary for the normal development of the plant, in this case manganese, an application of the lacking nutrient will result in a considerable increase in plant development and dry matter production, and a more economical use of the available soil moisture.

From the above considerations it is clear that the natural fertility of a soil has a considerable influence on transpiration efficiency, and a shortage in the supply of any essential nutrient will increase the water cost of producing dry matter. Where any soil nutrient is lacking, assimilation and dry matter production will be comparatively small in relation to transpiration, and the transpiration ratio will be high. Where these deficient nutrients are made good by the application of the appropriate fertilizers, assimilation increases without a corresponding increase in the amount of water transpired, with the result that the transpiration ratio is lowered.

SUMMARY.

The influence of (1) species, (2) environment, (3) growth stage, (4) defoliation, (5) fertilizers, on the water requirement of pasture species has been investigated.

1. Pasture species showed considerable variation in their water requirements. Of the species tested the lowest transpiration ratios were recorded for winter-growing annuals characterized by early maturity, and the highest transpiration ratios for perennial species adapted to high rainfall conditions.

2. The intensity of the environmental conditions, particularly during the critical period of maximum growth, had a marked influence on the water requirements of pasture plants. A high degree of correlation was found to exist between the transpiration of pasture plants and the evaporation from a free water surface.

3. The water cost of producing dry matter showed a marked increase as pasture plants advanced towards the mature stage.

4. The effect of defoliation on the transpiration ratio of perennial grasses varied according to the severity of defoliation applied. In no case was the transpiration ratio increased, and with frequent defoliations the transpiration ratio was substantially reduced.

5. A shortage of any essential nutrient in the soil was found to increase the transpiration ratio of pasture plants. On soils lacking either available phosphate, nitrogen or manganese the transpiration ratio was significantly and substantially reduced by an application of the appropriate fertilizer.

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- Williams, R. F. "An Analysis of the Effect of Phosphorus Supply on Transpiration Ratio in Plants." Aust. Jour. Exp. Biol. & Med. Sci. 13: 49. 1935.

A. E. V. RICHARDSON.

H. C. TRUMBLE.

A Census Study of Stubble-Sown Oats with and without Sulphate of Ammonia

During the experiments with sulphate of ammonia on stubble-sown cereals conducted at the Waite Institute, census work was undertaken to find out in what way the fertilizer affected the crops to produce the increased yield.

With wheat (1) it was found that sulphate of ammonia increased the tillering, which in turn gave more heads per foot-length of drill row at harvest. The yields tended to be proportional to the number of heads formed per foot in both the treated and untreated plots.

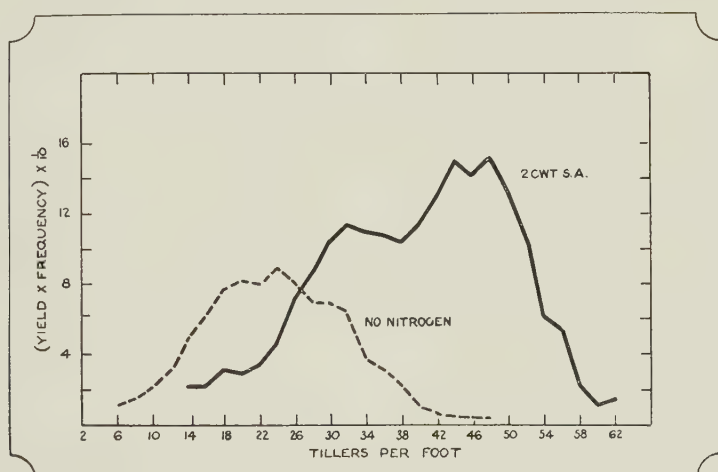


Fig. 1. Contribution of tiller classes to yield of oats treated with and without sulphate of ammonia.

With barley also (2) sulphate of ammonia caused increased tillering, resulting in more heads per foot and a higher yield.

With oats, however (2), although the sulphate of ammonia almost doubled the number of tillers formed per foot, there was a very high mortality among the tillers, only 37.4 per cent. of them forming panicles at harvest. Thus the number of panicles per foot at harvest was not very different in the no nitrogen and the 2 cwt. sulphate of ammonia plots, yet the respective yields were 40.91 bushels per acre and 75.01 bushels per acre.

This behaviour of oats when treated with sulphate of ammonia was investigated more fully in 1935.

Method.

In six plots receiving no nitrogen and six plots receiving 2 cwt. sulphate of ammonia at seeding, sample foot-lengths of drill row were marked by jarrah stakes on each of the seven inmost drill rows, there being three diagonals of seven samples, giving twenty-one samples in each plot, and 126 samples in all for each treatment.

The tillers present in each foot-length were counted at the maximum tillering stage in August. Each foot-length was harvested separately and bagged, and later the panicles were counted, and threshed in a miniature threshing machine, the yield being recorded for each foot-sample.

Results of the Census.

The averaged results of the census are shown in the following table.

Effect of Sulphate of Ammonia on Oats, 1935.

Census.	No Nitrogen.	2 cwt. Sulphate of Ammonia per acre.
No. of tillers per foot at maximum tillering	20.70	36.48
No. of panicles per foot at harvest	10.47	12.02
Percentage survival of tillers	50.58	32.95
Mean yield of grain in grams per foot	7.57	16.23

It will be seen that sulphate of ammonia caused an increase in tillering, from 20.70 tillers per foot to 36.48 tillers per foot, but the very low survival rate with the nitrogenous dressing led to only a small difference in the number of panicles formed at harvest. There was, however, a big difference in the mean yield per foot.

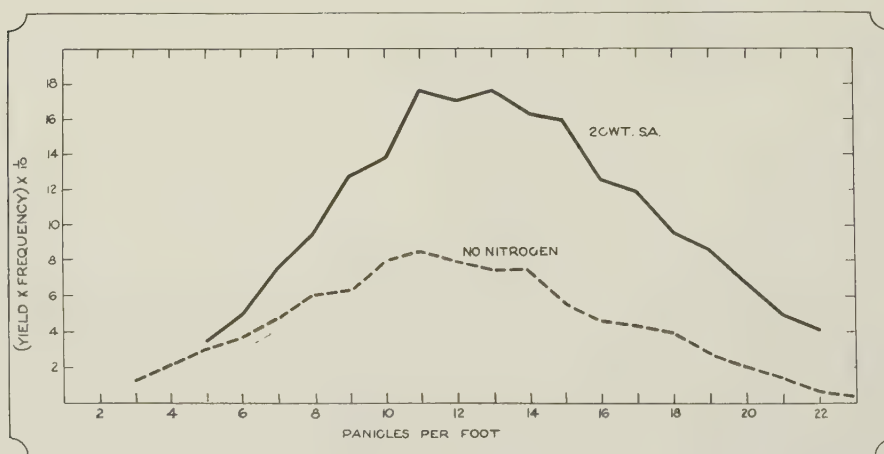


Fig. 2. Contribution of panicle classes per foot to yield of oats treated with and without sulphate of ammonia.

Grouping the individual foot-length samples into classes for tiller numbers per foot, the contribution to the yield of any particular tiller class is shown in Fig. 1, where the product of the yield per foot and frequency is plotted against the tiller classes. It will be seen that the tiller range effectively contributing towards the yield has been shifted from 12 to 34 approximately with no nitrogen, to from 24 to 56 with 2 cwt. of sulphate of ammonia.

Comparing this with Fig. 2, which shows the contribution of the panicle classes per foot to the yield, it is seen that there has been only a very slight change in the range of panicles per foot effectively contributing to the yield.

The yield per panicle with 2 cwt. of sulphate of ammonia has been considerably increased, however (Fig. 3), right throughout the range of panicle numbers per foot occurring in the crop.

It is interesting that with wheat and barley forming a more compact head than the panicle of oats, and capable of less variation, the effect has been to pro-

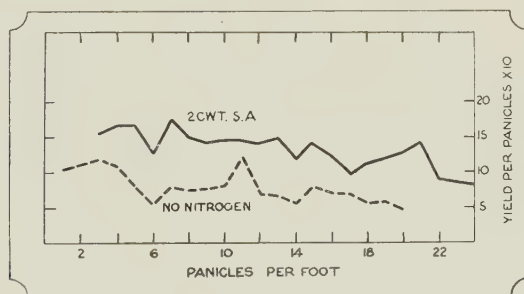


Fig. 3. Yield per panicle with oats treated with and without sulphate of ammonia.

duce more heads per foot with sulphate of ammonia, rather than to increase the size of the heads, whereas with the looser association of spikelets which form the oat panicle, the size has been increased rather than the number.

It will be noticed that with both dressings the yield per panicle tends to fall as the number of panicles per foot increases. This is a little more noticeable with the 2 cwt. sulphate of ammonia dressing.

The very low survival rate of the tillers to form panicles with the nitrogenous dressing suggests the possibility of non-maturing tillers affecting the yield.

In Fig. 4, opposite each panicle class per foot is shown the yield per panicle and the number of non-maturing tillers per foot for that class. It will be seen that the steady fall in the yield per panicle with the increasing numbers of panicles per foot is associated with a steady rise in the number of non-maturing tillers per foot. That is to say, that the percentage survival of tillers falls off gradually as panicle numbers per foot are increased.

Evidence has been obtained (unpublished data) that for a number of wheat varieties for any particular number of heads per foot, increasing numbers of non-maturing tillers cause decreased yield per head.

From Fig 4 it seems possible that the fall in yield per panicle with increasing panicles per foot is due to the combined effect of (1) the competition of one panicle with another within the foot-length, and (2) the competition of non-maturing tillers in the foot-length. With the samples from the no nitrogen plots, with their better survival rate and consequently fewer non-maturing tillers, although nearly the same number of panicles is formed per foot, the fall-off in yield per panicle is not so marked, nor does the number of non-maturing tillers increase so definitely with increasing panicle numbers per foot.

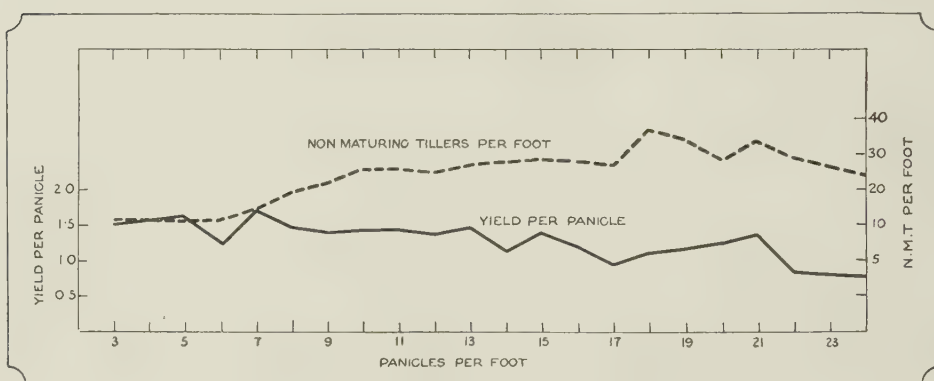


Fig. 4. Yield per panicle in relation to non-maturing tillers.

It is suggested that the more rapid falling-off in yield per panicle with the nitrogenous dressing is due to the presence of increasing numbers of non-maturing tillers.

Under poorer moisture conditions this effect would become even more important.

SUMMARY.

1. In a census study of stubble sown oats grown with no nitrogenous fertilizer and with 2 cwt. of sulphate of ammonia, it was found that the sulphate of ammonia caused greatly increased tillering, but that the survival rate was much reduced, resulting in almost the same range of panicles per foot contributing to the yield in both treatments.

2. The yield per panicle, however, was much increased by the sulphate of ammonia, this being the manner in which the sulphate of ammonia caused the

greatly increased yield. This is in contrast with the results found previously for wheat and barley.

3. It was suggested that the presence of more non-maturing tillers per foot with the sulphate of ammonia dressing caused the more rapid fall-off in the yield per panicle with increasing panicle numbers per foot, compared with the falling-off observed with no nitrogen.

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H. C. GURNEY.

Papers Published by the Staff of the Waite Agricultural Research Institute 1933-1936

I. SOILS INVESTIGATIONS.

(A) SOIL CLASSIFICATION.

1. J. A. Prescott. Trans. Roy. Soc. Sth. Aust. 58: 10. 1934.

“The Composition of some Ironstone Gravels from Australian Soils.”

Analyses of the hydrochloric acid extracts of 17 samples of ironstone gravel from localities in Western Australia and South Australia. The quantities of Fe_2O_3 extracted vary from 22 per cent. to 74 per cent. Manganese is present in small amounts only. Absorption tests with alizarin suggest that possibly 1 per cent. or 2 per cent. of free alumina may be present.

2. J. A. Prescott, J. K. Taylor, and T. J. Marshall. Trans. Comm. I, Int. Soc. Soil Sci. A. 143. 1934.

“The Relationship between the Mechanical Composition of the Soil and the Estimate of Texture in the Field.”

From the experience gained during soil surveys in Australia a relationship between estimates of texture in the field and the mechanical analysis of mineral soils has been established. This relationship has been correlated with the system developed by workers in the United States.

3. J. A. Prescott. Jour. Aust. Inst. Agric. Sci. 1: 155. 1935.

“The Nomenclature of Soils.”

An account of the historical development of systems of soil nomenclature dealing with the Linnean, American and Russian contributions.

4. J. K. Taylor. Jour. Aust. Inst. Agric. Sci. 1: 111. 1935.

“Soil Colour Classes.”

The examination of the colour range of Australian soils by means of the Maxwell spinning disc using Munsell colours standardized by the U.S. Bureau of Standards. About 25 colours will be sufficient to give a good scale for field working.

5. J. S. Hosking. *Soil Res.* 4: 253. 1935.

“The Carbon-Nitrogen Ratios of Australian Soils.”

The variation in the carbon-nitrogen ratio of Australian soils is discussed in the light of the frequency distribution of these values. No general relationship is apparent between carbon-nitrogen ratio and soil type, or climate or depth of profile. Distinctive differences in the distribution of values for the soils associated with the two major phases of the vegetation associations, the woodland or forests and the grasslands, are shown.

(B) SOIL SURVEYS.

6. T. J. Marshall and P. D. Hooper. *C.S.I.R. Bull.* 86. 1935.

“A Soil Survey of the Berri, Cobdogla, Kingston and Moorook Irrigation Areas.”

The report of a soil survey of 21,500 acres of irrigable land in five horticultural settlements. Twenty soil types are recognized falling into two groups—the river terrace and the mallee soils.

The main physical and chemical characteristics of the soil types are presented. The reaction of all the soil types is alkaline with greater alkalinity in the mallee soils.

The behaviour of each type under irrigation is discussed. The effect of irrigation on the redistribution of the salts in the original soil is examined.

A general discussion of the soil conditions in each of the five settlements is given.

7. J. S. Hosking. *Trans. Roy. Soc. Sth. Aust.* 59: 168. 1935.

“A Comparative Study of the Black Earths of Australia and the Regur of India.”

Comparisons have been made of the distribution, morphology and mechanical and chemical characteristics so far as soil samples were available of the Australian black earths and the regur of India.

The limitation to the geographical distribution of both types is shown to be imposed by the same geological exposures and by the same climatic factors when considered on an annual basis. The soils are characterized by their grey to black colour, sufficiently explained as due to their organic matter, an extremely heavy texture, and the presence of calcium carbonate. The potash content of the soils is low and variable. Phosphoric acid is high in the Australian soils though much lower in the Indian soils. A high degree of base saturation characterizes both types but while the Indian soils are of the high calcium type, certain of the Australian soils show a

high proportion of magnesium to calcium. The soil reaction is predominantly alkaline. There is a marked divergence in the organic matter content; the low values for the Indian soils may possibly be explained by the higher temperatures pertaining in India.

From a study of the close similarity in the various characteristics of these soils, the two types may definitely be considered to belong to the same group, the Indian soils in all probability representing the most tropical occurrence of the black earths.

8. T. J. Marshall and J. S. Hosking. C.S.I.R. Pt. 3. Bull. 85.

“Studies on the Phosphorus Requirements of Sheep. Part 3. A Soil Survey of the Area under the Control of the Division of Animal Nutrition at ‘Dismal Swamp’.”

A soil survey of 700 acres of the Dismal Swamp Estate. Two soil types have been identified and their mechanical and chemical characteristics described.

9. J. S. Hosking and G. A. Greaves. Jour. Roy. Soc. West Aust. 22: 71. 1936.

“A Soil Survey of an Area at Gingin, Western Australia.”

A soil survey, carried out in co-operation with the Department of Agriculture in Western Australia, of 15,500 acres of an area associated with cretaceous sediments. Eleven major soil types are recognized and described. Apart from the *Gingin clay*—a rendzina found on the Gingin chalks—the soils are generally of a very sandy nature. Detailed chemical and mechanical analyses are given, and the results discussed.

A problem of live stock, enzootic ataxia, associated with the area, is also discussed.

10. J. A. Prescott and J. S. Hosking. Trans. Roy. Soc. Sth. Aust. 60: 35. 1936.

“Some Red Basaltic Soils from Eastern Australia.”

The chemical and physical characteristics of some red soils derived from tertiary basalts in Queensland and New South Wales are discussed. The clay content is higher than would be expected from estimates of texture in the field or from the physical properties.

Relationships between the moisture equivalent and the base exchange capacity of the soil and the chemical composition of the clay fraction are examined. There are notable correlations between the exchange capacity and the silica-alumina ratios of the clays, and between exchange capacity and moisture equivalent. An appreciable proportion of the iron oxide occurring in the clay fraction is in a free state.

11. T. J. Marshall and A. Walkley. C.S.I.R. Bull. (In press).

“A Soil Survey of the Coomealla, Wentworth (Curlwaa) and Pomona Irrigation Settlements, New South Wales.”

A soil survey of 5,850 acres near the junction of the Murray and Darling Rivers. The soils of Curlwaa and Pomona, all of which belong to the river flat group, cover a big range of texture and reaction. Thirteen types have been defined and fully described. Water table and salinity troubles are common.

The soils of Coomealla belong to the broad zonal group of mallee soils. Ten types have been described. The relation between vegetation, slope and soil type of an area of virgin land is discussed.

Detailed chemical and mechanical analyses have been carried out on 140 soils.

(C) LABORATORY TECHNIQUE.

12. J. A. Prescott and C. G. Stephens. Jour. C.S.I.R. 7: 185. 1934.

“The Determination of the Lime Requirement of Soils in association with Soil Surveys.”

An adaptation of the Veitch (1902) method. Several portions of 30 gm. of soil are evaporated in basins with distilled water and varying amounts of saturated lime water. After drying and grinding, the hydrogen-ion concentration of the treated soils is determined. The amount of lime required to bring the original soil to any predetermined pH value is read off from the buffer curve.

Where such buffer curves have been established for a given soil type or group of related types, it is possible to estimate the lime requirement of any sample directly from the pH value alone or from the pH value in combination with some other factor such as loss on ignition.

13. C. S. Piper and A. Walkley (Collaborators in Report of the Organic Carbon Committee). Trans. 3rd Internat. Congress Soil Science 1: 114, and 3: 82.

Nine soils were examined for calcium carbonate by the Hutchinson-MacLennan method, and for organic carbon by a dry combustion method (C.S.P.).

Organic carbon was also determined on the same soils using three different rapid titration methods (A.W.).

The methods and results were discussed and criticized in detail.

14. Allan Walkley. Jour. Agric. Sci. 25: 598. 1935.

“An Examination of Methods for Determining Organic Carbon and Nitrogen in Soils.”

The details of the Dennstedt dry-combustion method and of the Bangor wet-combustion method were examined and some modifications and simplifications suggested. For many heavy soils the addition of water prior to Kjeldahl digestion was found to be convenient but not essential. Fine grinding of the soil was as effective as the addition of water.

The rapid dichromate titration method of Walkley and Black for soil carbon gave satisfactory approximate results. The details of the technique were improved and methods were devised for overcoming disturbances due to chlorides. The presence of calcium carbonate caused no interference. The method is particularly suited to the analysis of soils of similar types.

15. C. S. Piper. Jour. Soc. Chem. Ind. 53: 392T, 1934, and 54: 157T, 1935.

“The Volumetric Determination of Potassium by the Cobaltinitrite Method.”

The precipitation of potassium as sodium potassium cobaltinitrite has been studied and a method evolved which enables this element to be determined with accuracy. The method is of particular value for the determination of the small amounts of exchangeable potassium that occur in soils although larger amounts may be determined with equal accuracy. Calcium, magnesium, iron, aluminium, sulphates, chlorides and phosphates do not interfere.

The factors governing the composition of the precipitate have been investigated and a formula worked out to enable the amount of potash present to be calculated from the permanganate titration value of the precipitate.

In the second paper attention has been drawn to a source of error which occurred in a series of determinations owing to the presence of small quantities of ammonium as an impurity in a batch of reagent cobalt nitrate. Under such conditions ammonium is co-precipitated with potassium, but this occurred to a greater degree in the actual determinations, in the presence of potassium, than in blank determinations. Thus the blank did not give a true correction and high results were obtained for potassium. The importance of proving the absence of ammonium in all reagents used in this method was stressed. With reagents of satisfactory quality the blank titration did not exceed 0.5 ml. of $\frac{N}{20}$ permanganate.

16. C. S. Piper. Jour. C.S.I.R. 9: 113. 1936.

“Exchangeable Hydrogen in Soils.”

Definitions of saturated soils and exchangeable hydrogen are discussed and, for pedological purposes, it is considered that a saturated soil should be regarded as one in equilibrium with calcium carbonate.

A laboratory method for the determination of exchangeable hydrogen, in accordance with this concept of a saturated soil, has been developed. The soil is shaken with two *m*-nitrophenol buffers of different basicity and the change in basicity measured by titration. The amount of base unsaturation of the soil (or the exchangeable hydrogen) is then determined by interpolation from these values.

The values so obtained agree with those obtained by Bradfield's residual carbonate method and a large series of naturally occurring calcareous soils, i.e. saturated by definition, were also examined and found to give zero values for exchangeable hydrogen by the proposed method.

17. C. S. Piper and C. G. Stephens. Jour. C.S.I.R. 9: 125. 1936.

"A Comparison between Schofield's Para Nitrophenol Buffer Method and the Method of Prescott and Stephens for the Determination of Lime Requirement of Soils."

The values obtained for a series of 71 Tasmanian soils by Schofield's rapid *p*-nitrophenol method for the determination of lime requirement to pH 7 have been compared with the corresponding values determined by Prescott and Stephens' modification of the Veitch method.

The mean value for the regression equations connecting the two sets of results was found to be

$$X = -1.98 + 1.272 y$$

X representing the lime requirement to pH 7 by Prescott and Stephens' method and *y* the corresponding value by Schofield's method.

Schofield's method was found to be rapid, and to give reproducible values. Its use in connection with surveys of acid soils was recommended.

18. J. S. Hosking. Jour. Proc. Aust. Chem. Inst. 3: 172. 1936.

"The Determination of Cobalt, Nickel, Copper and Zinc in Soil Extracts."

Details are given for the separation of the metals—cobalt, nickel, copper and zinc—from each other and from iron, aluminium and other interferants, and their gravimetric estimation by means of organic reagents in the hydrochloric extracts of soils.

19. Allan Walkley. Jour. C.S.I.R. 9: 321. 1936.

"A Note on the Use of Caustic Soda as a Dispersing Agent in the Mechanical Analysis of Soils."

Some soils from the Murrumbidgee Irrigation Area were found to give much higher clay figures when dispersed with caustic soda, than when ammonia was used for this purpose. Caustic soda is recommended for future work.

20. C. S. Piper. Jour. C.S.I.R. 9: 245. 1936.

“The Boron Status of South Australian Apples.”

The boron content of 48 samples of apples, representing 19 localities throughout the more important apple-growing areas of South Australia, has been determined. The amount found ranged from 12 parts to 30 parts of elementary boron per million parts of dry matter, and averaged 21 p.p.m. No correlation was observed between the boron content and the incidence of bitter pit, nor between boron content and vigorous or weak trees. By comparison with figures published for New Zealand, the values obtained suggest that a deficiency of boron is not likely to occur in the soils of the areas examined.

21. C. S. Piper. Jour. Aust. Chem. Inst. (in press).

“The Determination of Sodium and Potassium.”

A review of the methods available for the determination of sodium and potassium. For small quantities of these elements, the uranyl magnesium acetate method is recommended for sodium, and the cobaltinitrite method for potassium. For larger quantities of potassium the perchlorate method is preferred.

II. FIELD CROPS, PASTURES (INCLUDING MINERAL CONTENT OF PASTURES), PLANT NUTRITION, PLANT BREEDING.

(A) FIELD CROPS.

22. J. A. Prescott. Pan Pacific Sci. Congress (5th) Vancouver, 1933. 4: 2657.

“The Nitrogen Problem in the Australian Wheat Belt.”

An examination of the need for nitrogenous fertilizers in the wheat areas of Australia. The relative importance of soil moisture conservation and of nitrate accumulation during bare fallowing is discussed. The responses of wheat to nitrogen fertilizers in various recorded experiments are examined. Such responses may be expected under certain special conditions of non-fallowing, principally where wheat is grown on cereal stubble. Other non-fallows, such as stubble grazing, pea stubble and lupin stubble vary in their ability to supply nitrogen to a following wheat crop.

23. A. E. V. Richardson and H. C. Gurney. Jour. Agric. Sth. Aust. 38: 954. 1935.

“Nitrogen in Relation to Cereal Culture.”

Investigations on the effect of nitrogenous fertilizers on the growth of wheat, oats and barley at the Waite Institute for seven seasons are recorded.

The response of wheat to nitrogenous fertilizers was not sufficient to be profitable on well-worked fallow, but on stubble land mean increases of 5.4 bushels per acre over a five-year period were obtained.

Equivalent dressings of nitrogen (23·4 lb. per acre) applied in various forms to wheat on stubble showed that nitrate of soda gave the largest increases. Dressings of nitrate of soda, sulphate of ammonia, nitrochalk and urea were profitable with normal values for wheat.

Striking and profitable increases in the yield of oats and barley were obtained with sulphate of ammonia on stubble land.

Census studies showed that the increases in yield of wheat and barley were due mainly to the increase in the number of ear-bearing tillers, and with oats to increased panicle development.

(B) PASTURES (INCLUDING MINERAL CONTENT OF PASTURES).

24. H. C. Trumble and J. G. Davies. C.S.I.R. Bull. No. 80. 1934.

“The Establishment, Persistency and Productivity of Selected Pasture Species on an Irrigated Reclaimed Swamp.”

Preliminary and exploratory investigations were carried out over a period of 89 weeks to determine the most suitable pasture species, strains and mixtures for an irrigated reclaimed swamp.

It was concluded that a simple seeds mixture of truly permanent strains of perennial rye-grass, cocksfoot, white clover and red clover was particularly suitable. A mixture of *Phalaris tuberosa*, *Poa pratensis*, and white clover also gave good results.

The yields of certain mixtures were approximately double those of the best perennial rye-grass pure swards, and 77 per cent. greater than that of lucerne. Relatively low seeds rates proved satisfactory.

25. A. B. Cashmore. C.S.I.R. Bull. 81. 1934.

“A Comparative Study of *Lolium perenne* and *Phalaris tuberosa* at Varying Stages of Growth.”

Perennial rye-grass proved to be more vigorous in establishment and early growth than *Phalaris tuberosa*, outyielding the latter in the first year by more than 100 per cent. In the second year the rye-grass was no more vigorous than in the first year and was considerably outyielded by *Phalaris*. Root penetration in *Lolium* reached 52 inches in both seasons; *Phalaris* penetrated to 76 inches in the first season and 91 inches in the second season. Suppression of *Phalaris* by *Lolium* in the first season was attributed to root competition in the surface layers of soil.

Under the conditions of the Adelaide environment, *L. perenne* is the more rapidly establishing and aggressive species; once establishment has been effected, however, *P. tuberosa* is the more persistent and productive species.

26. H. C. Trumble and A. B. Cashmore. *Herbage Reviews* 2: 1. 1934.

"The Variety Concept in relation to *Phalaris tuberosa* and Allied Forms."

The forms of *Phalaris tuberosa* grown in Australia originated from a limited quantity of material grown at Toowoomba prior to 1904.

Little ecotypical selection has occurred owing to the limited original material, a short time interval, poor capacity for re-generation from seed and persistence and adaptability of the single plant.

On the other hand, Mediterranean material shows differences according to origin and has proved inferior to the cultivated Australian forms.

Strain production has proceeded on the basis of single plant selection and the inter-pollination of selected parental types.

27. J. G. Davies, A. E. Scott and K. M. Fraser. *C.S.I.R. Bull.* 83. 1934.

"Natural Pastures: Their Response to Superphosphate."

Investigations were conducted at the Waite Institute and at the Experimental Farm, Kybybolite, with a view to ascertaining the effect of phosphatic fertilizers on the carrying capacity, nutritive value and mineral content of natural pastures in the better rainfall areas of South Australia. Merino wethers were maintained exclusively on the pastures throughout four seasons and were weighed at periodic intervals. The weight and quality of the wool produced by the sheep, and the changes in the yield and botanical composition of the grazed pastures were also determined.

At each centre the carrying capacity of the natural pasture was materially increased by the application of superphosphate, but no important differences were observed in the mean live-weight or the quantity or quality of wool produced by each sheep as a result of top-dressing with phosphate. The sheep fluctuated markedly in live-weight with the period of the season. The application of superphosphate produced marked changes in the botanical and chemical composition of the pasture.

28. H. C. Trumble and C. M. Eardley. *Jour. Agric. Sth. Aust.* 38: 1392. 1935.

"The Weed *Citrullus colocynthis* (Colocynth), a Perennial Wild Melon."

Attention has been drawn to the occurrence of a perennial wild melon, possessing certain features tending to render it a serious weed under cultivation, in the Waikerie and Swan Reach districts. The species had not previously been recorded in South Australia. A description has been given enabling the weed to be readily identified.

29. H. C. Trumble. *Jour. C.S.I.R.* 8: 195. 1935.

"A Note on the origin of 'Toowoomba Canary Grass' (*Phalaris tuberosa* L.)."

The available literature relating to the origin of this grass has been reviewed and its early history interpreted.

It is concluded that the grass was introduced under the name "*Phalaris commutata*", and that it originated in Italy.

Botanical and agronomic examination indicate that the grass is the same taxonomically as *P. tuberosa* L., but is greatly superior for agricultural purposes to those forms of the species which have been obtained direct from Mediterranean countries.

30. H. C. Trumble. Jour. Agric. Sth. Aust. 38: 1460. 1935.

"The Relation of Pasture Development to Environmental Factors in South Australia."

The main types of natural and seeded pasture in South Australia are discussed in relation to soil and climatic factors; and the location of the grazing areas and the intensity of stocking from point to point are related to climax vegetation.

The effect of top-dressing with soluble phosphate and the influence of rainfall on natural pastures are discussed and it is shown that there is a significant trend from natural to seeded pastures.

The influence of phosphatic and nitrogenous manuring on botanical changes and productivity in pastures is dealt with, and a list of pasture mixtures for specified environmental conditions is given.

31. H. C. Trumble. Jour. Aust. Inst. Agric. Sci. 1: 117. 1935.

"The Grass-legume Association in Pastures."

The concept of the grass-legume association as a basic unit of grassland is developed. The postulate is put forward that the combination of grass and legume is indispensable for maximum productivity, as well as for satisfactory animal nutrition. Fluctuations in the grass: clover ratio in pastures are attributed largely to variations in the relative supplies of available nitrogen and phosphorus in the soil. It is concluded that a transfer from legumes to associate non-legumes may occur but that the question is not a simple one and is probably conditioned by variation in certain factors of the root environment.

32. H. C. Trumble and E. A. Cornish. Jour. C.S.I.R. 9: 19. 1936.

"The Influence of Rainfall on the Yield of a Natural Pasture."

The influence of annual, seasonal and monthly rainfall on the yield of unfertilized and top-dressed natural pasture for a period of ten seasons at the Waite Institute has been investigated by correlation and regression, and it has been found that the correlation is strongest in the period April to June inclusive, which coincides with the early stages of seasonal growth.

The effectiveness of autumnal and early winter rainfall and the relative ineffectiveness of late winter and spring rainfall in determining yield

appear to be associated with the type of pasture investigated, which comprises species with a restricted growing period and a limited capacity for production.

33. C. M. Donald. Jour. Aust. Inst. Agric. Sci. 2: 122. 1936.

“Strain Variation in Strawberry Clover (*Trifolium fragiferum* L.) and Prairie Grass (*Bromus unioloides*, H.B. et K.).

Investigations with a view to strain selection and improvement have been commenced with these two species. Fifty seed samples of *Bromus* species including 29 of prairie grass were sown as single plants at the Waite Institute and under irrigated conditions at Wood's Point in 1935. Similar work was commenced with 24 samples of strawberry clover. Much variation was evident between the different lines of both species. As in each case the species is normally self-fertilized, it is hoped that within a comparatively short period, strains will be available which are much superior to the available commercial types.

34. T. H. Strong. Jour. Aust. Inst. Agric. Sci. 1: 113. 1935.

“Lucerne Seed ‘Inoculation’ in Queensland.”

An account of a successful field trial of lucerne seed inoculation with an effective rhizobial strain in Queensland. A significant response to superphosphate was obtained in inoculated plots. A brief discussion of possible advantages in lucerne cultivation in Queensland is included.

35. T. H. Strong. Jour. Aust. Inst. Agric. Sci. 2: 120. 1936.

“Rhizobial Strain Variation in relation to the problem of Lucerne Seed Inoculation.”

A brief account of a pot experiment in which a wide range in effectiveness of strains of *Rhizobium meliloti* to lucerne was demonstrated. Isolations of *Rhizobium* were made from lucerne from various centres and the cultures tested upon lucerne grown in a medium free from nitrogen. An account of a successful field trial of seed inoculation at the Waite Institute is given, a mixture of selected effective strains being used.

36. R. E. Shapter. Jour. C.S.I.R. 8: 187. 1935.

“The Chemical Composition of Certain Pasture Species at Flowering and Maturity.”

Chemical analyses of twenty characteristic species of pasture plants, including eleven grasses, four legumes and five miscellaneous species, grown under identical cultural conditions in pots were recorded. Wide variations were shown to occur between the species within each group.

Soluble ash values were not characteristic for any of the groups; the quantities found overlap from one group to another. In contradistinction to this the legumes had very low insoluble ash contents compared with grasses, both in leaf and stem and in seed.

Two species of *Hordeum* gave lower values for ether extract in seed than in leaf and stem.

Seeds of legumes were considerably richer in ether extract than seeds of most of the grasses, but *Phalaris minor* gave a remarkably high value (7.6 per cent.); *Trifolium subterraneum* was prominent among the legumes with 15.16 per cent.

The seeds all showed high concentrations of phosphorus and *P. minor* is again prominent among the grasses with 1.12 per cent. (P_2O_5).

Erodium botrys amongst the miscellaneous species was outstanding in that its contents of nitrogen and phosphorus are similar to those found for legumes; its soluble ash is the highest recorded. The seed, however, is not specially rich in nitrogen and has a medium phosphorus content.

(C) PLANT NUTRITION.

37. A. H. K. Petrie. Aust. Jour. Exp. Biol. & Med. Sci. 12: 99. 1934.

“The Drift of the Content of Potassium and Calcium with Age in Plants.”

A partial interpretation is presented of the characteristic drifts in the K and Ca contents of the whole of an annual or annually renascent plant, or of a single leaf or shoot thereof. K occurs in the plant entirely in the ionic state, in cell-sap and cytoplasm; Ca, in addition to being present in the ionic state in these phases, is also fixed chemically and probably almost irreversibly. The amounts of sap and cytoplasm probably rise to a maximum at maturity and then decline. The absolute amount of K may be correlated with this drift, loss setting in at such time after maturity as the amounts in the two phases have reached an equilibrium. The same correlation, so far as concerns the rise, may hold for Ca, although here the accumulation is supplemented by fixation. Loss of Ca is probably prevented by low mobility and fixation.

Provided the K-ion concentrations of these phases do not rise too rapidly, the fact that the percentages of sap and cytoplasm probably fall from adolescence to death may account for the decline in relative K content. The decline in relative Ca content cannot be analysed, since the drift in the rate of fixation is not known; but continued fixation may be a factor in the maintenance of the relative content after maturity. Some experimental data obtained with *Lolium perenne* conform, as far as they can be analysed, to this partial interpretation of the drifts.

38. R. F. Williams. Aust. Jour. Exp. Biol. & Med. Sci. 13: 49. 1935.

“An Analysis of the Effect of Phosphorus Supply on Transpiration Ratio in Plants.”

Transpiration ratios (ratio of water transpired to the amount of dry matter formed) are presented for Algerian oats (*Avena sativa* Linn.) over five different time intervals all commencing from the same early stage in the life cycle. An increase in phosphorus supply from a low to a moderate amount has the effect of lowering the ratio for each time interval. An additional supply of phosphorus produces no further effect.

Except in the case of the shortest time interval, the reduction in the ratio is shown to be due to a decrease with treatment in the transpiration rate per unit weight of plant consequent on (a) a decrease with treatment in the transpiration rate per unit weight of leaf, and (b) a decrease with treatment in the leaf weight ratio during part of the life cycle.

Increased phosphorus supply tends to raise the transpiration ratio indirectly through an effect on growth, but this tendency is more than balanced by the above-mentioned effect of treatment on transpiration rate. The interaction of the factors is examined by a graphical method of analysis.

For the shortest time interval the effect of treatment on growth is reversed, and the reduction in transpiration ratio is due to the growth factor rather than to any effect of treatment on transpiration rate.

A significant correlation is shown between the relative transpiration rate per unit weight of leaf and the nitrogen content of the leaves.

39. L. A. T. Ballard and A. H. K. Petrie, with a statistical appendix by E. A. Cornish. Aust. Jour. Exp. Biol. & Med. Sci. 14: 135. 1936.

“Physiological Ontogeny in Plants and its Relation to Nutrition. 1. The Effect of Nitrogen Supply on the Growth of the Plant and its Parts.”

This paper is the first of a series devoted to the study of physiological ontogeny and defines the effects of different initial supplies of nitrogen on wheat and Sudan grass grown in sand culture. Treatment effects on drifts with time in the dry weights of the whole plant and its parts, in the relative growth rate, the leaf weight ratio and the unit leaf rate are presented, and discussed in relation to the data of other workers.

40. R. F. Williams. Aust. Jour. Exp. Biol. & Med. Sci. 14: 165. 1936.

“Physiological Ontogeny in Plants and its Relation to Nutrition. 2. The Effect of Phosphorus Supply on the Growth of the Plant and its Parts.”

This second paper of the series defines the effects of different initial supplies of phosphorus on oat plants grown in sand culture. Treatment

effects on drifts with time in the same attributes as are considered in the first paper of the series are presented. A brief comparison is made of the effects of increasing nitrogen and phosphorus supplies upon these attributes.

(D) PLANT BREEDING.

41. I. F. Phipps. Jour. Aust. Inst. Agric. Sci. 2: 107. 1936.

“Recent Developments in Genetics and Plant Breeding.”

III. FUNGUS AND VIRUS DISEASES OF PLANTS.

42. S. D. Garrett. Biol. Reviews 9: 351. 1934.

“Factors affecting the Pathogenicity of Cereal Foot-rot Fungi.”

A review of work carried out at the Waite Institute and elsewhere on the relationship between soil factors, particularly temperature, moisture and microbiological content, and the occurrence of cereal foot-rots. Stress is laid upon an adequate recognition of the biological element in different soils not only as a determinant of the kind of foot-rot developing, but also of its severity. Experimental work on the influence of soil temperature and moisture content on the development of cereal foot-rots are interpreted in the light of the conception that biological antagonism is a factor which modifies the influence of changes in the physical environment of the soil. In this light many of the contradictory results obtained by different investigators can be reconciled and their results brought into harmony.

43. D. B. Adam. Jour. Agric. Sth. Aust. 39: 600. 1935.

“Leaf Mould: A Disease of Glasshouse-grown Tomatoes.”

“Leaf mould” (*Cladosporium fulvum*) is recorded apparently for the first time on tomatoes grown in South Australia. The history of the disease since its introduction into the Commonwealth is traced. A description of the symptoms is given together with notes on the biology and methods of control of this disease. These notes are based principally on English investigations where “leaf mould” is well known and has been studied closely.

44. G. Samuel, R. J. Best and J. G. Bald. Anns. Appl. Biol. 22: 508. 1935.

“Further Studies on Quantitative Methods with Two Plant Viruses.”

The arrangement of experiments for intercomparison of a number of virus suspensions was discussed and the use of randomized blocks and Latin squares was recommended. It was shown that provided sufficient inoculum to cover the leaf is used, the number of lesions produced is independent of the amount of inoculum. The conditions to which test plants were exposed shortly before inoculation were shown to affect the number of

lesions produced by a given inoculum. The number of lesions produced by otherwise similar inocula was shown to be influenced by the pH value and electrolyte content of the inocula, and it was recommended that these factors should be standardized in quantitative work with plant viruses. Preliminary tests of some chemicals on the activity of tomato spotted wilt inocula were recorded.

45. R. J. Best. *Jour. Aust. Inst. Agric. Sci.* 1: 159. 1935.

“The Effect of Environment on the Production of Primary Lesions by Plant Viruses.”

A discussion of some factors which affect the production of primary lesions and their bearing on the quantitative estimation of relative concentrations of active virus units. Using a purified preparation of tobacco mosaic virus (separated from the juice by precipitation at the isoelectric point of the virus—pH 3·4) it was shown that the number of lesions which generally develop from a given inoculum varies with the temperature prevailing subsequent to inoculation. Some effects of different environmental conditions to which the test plants were exposed subsequent to inoculation on the number of lesions finally developed on tobacco leaves inoculated with tomato spotted wilt virus were described.

46. R. J. Best. *Aust. Jour. Exp. Biol. & Med. Sci.* 14: 1. 1936.

“Precipitation of the Tobacco Mosaic Virus Complex at its Isoelectric Point.”

The virus of ordinary tobacco mosaic is precipitated from the clarified juice of infected tobacco and tomato plants to various extents over the pH range 3 to 4. The point of maximum precipitation is at pH 3·4 where, under suitable conditions, more than 99 per cent. of the virus may be precipitated. Precipitation of the purified virus from solutions of the “isoelectric” precipitate in buffer solution of pH 7 takes place in the same way. The isoelectric point of the virus complex may therefore be taken as pH $3\cdot4 \pm 0\cdot1$.

The precipitate, which contained practically the whole of the virus, constituted about 0·3 per cent. of the clarified juice or 3 per cent. of the total solids of the crude juice. The average yield was 3 milligrams of virus per millilitre juice.

Relatively stable colloidal solutions of the precipitate were obtained by eluting it with buffer solutions of pH values between 2·8 and 2·3 or between 4·5 and 7·5, and these solutions contained the whole of the precipitated virus in an active condition. It was not found possible to separate the virus from the precipitate by selective elution either on the acid or on the alkaline side of its isoelectric point. From the evidence as a whole it

was concluded that the precipitate is the virus itself or a complex of virus with some fundamentally related substance present in the juice. Qualitative tests and its nitrogen content class the precipitate as a protein.

47. R. J. Best. Aust. Jour. Exp. Biol. & Med. Sci. 14: 199. 1936.

“Studies on a Fluorescent Substance present in Plants. 1. Production of the substance as a result of Virus Infection and some Applications of the Phenomenon.”

Primary lesions of tomato spotted wilt (T.S.W.) virus on *Nicotiana tabacum* were found to be surrounded by brightly fluorescent haloes when they were viewed under filtered ultra-violet light. The fluorescence is caused by a water soluble, relatively stable organic substance which is present in small quantities in healthy plants but is produced in much larger quantities as a result of virus activity. Some properties of the substance are recorded. As a result of an examination of this effect on other host plants and of the effect of tobacco mosaic virus it was found that enhanced production of the substance followed virus infection of many but not all host plants, and that the reaction was not specific for T.S.W. virus, but appeared to have a wider significance in connection with injury to the tissues. A close parallelism appears to exist between the presence of the substance in healthy plants and the type of infection resulting after inoculation with T.S.W. virus.

48. R. J. Best. Aust. Jour. Exp. Biol. & Med. Sci. 14: 223. 1936.

“The Effect of Light and Temperature on the Development of Primary Lesions of the Viruses of Tomato Spotted Wilt and Tobacco Mosaic.”

Under constant conditions of light and temperature the curves relating the number of lesions to time were found to be sigmoid in form and to approach limiting values. This value was 30 per cent. higher at 20° C. than at 15° C. for both virus-host combinations. The time interval between inoculation and the time of maximum rate of appearance of lesions varied with temperature and at constant temperature appeared to be a constant for any one virus-host combination. This interval was found to be 50 per cent. longer at 15° C. than at 20° C. for mosaic lesions on *Nicotiana glutinosa* and 60 per cent. longer for tomato spotted wilt (T.S.W.) lesions on *Nicotiana tabacum*. The time taken for T.S.W. lesions to attain their maximum rate of appearance was 60 per cent. longer than that for mosaic lesions at 20° C. and 50 per cent. longer at 15° C. Sunlight was found to exert an inhibiting action on the appearance of T.S.W. lesions on *N. tabacum*. A similar but much feeble effect was observed with artificial light. For tobacco mosaic virus on one *N. glutinosa* leaf an average infective unit of 1.1×10^{-9} gm. virus per lesion was obtained.

49. R. J. Best and G. Samuel. *Anns. Appl. Biol.* 23: 509. 1936.

"The Reaction of the Viruses of Tomato Spotted Wilt and Tobacco Mosaic to the pH value of Media containing them."

The interpretation of lesion counts in terms of the relative concentration of active virus units was discussed and a dilution curve for the virus of tomato spotted wilt was recorded. Activity-pH curves were constructed for the viruses of tomato spotted wilt and tobacco mosaic. Spotted wilt virus was rapidly inactivated at and below a pH value of 5 and above a pH value of 9. It remained active over the pH range of 6 to 9. Activity-time curves at constant pH value showed that in the case of tobacco mosaic virus at pH 9 a rapid fall in the concentration of active units to what appeared to be a constant level took place. A measure of reactivation was obtained on adjusting to pH 7 during the early stages of inactivation, but once the "equilibrium" state had been reached no reactivation was possible. Activity-pH curves for this virus showed that it remained active over the pH range 2 to 8, but was inactivated to various degrees above and below these values. Inactivation was complete at pH values of 0.35 and 12.5. It was pointed out that the results for tobacco mosaic virus were strong evidence for the non-organismal nature of this virus.

50. R. J. Best. *Aust. Jour. Exp. Biol. & Med. Sci.* 14: 323. 1936.

"The Relationship between the Activity of Tobacco Mosaic Virus Suspensions and Hydrion Concentration over the pH range 5-10."

The percentage inactivation of the virus of tobacco mosaic has been determined for various pH values over the pH range 5 to 10. Inactivation set in at a pH value of about 7.8 and the fraction inactivated was progressively larger with increasing pH values until at a pH value of 10.2 only about one-half of a per cent. of the virus added remained active. Between pH values of 8.0 and 8.9, corresponding with 21 per cent. and 90 per cent.

inactivation respectively, the ratio $\frac{[H^+]}{[\text{active virus}]}$ was found to be a constant, but this relationship did not hold at pH values below 8. It was concluded that inactivation of the virus was associated with the neutralization of acidic groups. The bearing of these results on the nature of the virus was discussed and it was suggested that the groups thus neutralized are an integral part of the chemically reactive prosthetic groups of the virus.

51. R. J. Best and G. Samuel. *Anns. Appl. Biol.* 23: 759. 1936.

"The Effect of Various Chemical Treatments on the Activity of the Viruses of Tomato Spotted Wilt and ordinary Tobacco Mosaic."

Suspensions of the virus of tomato spotted wilt (T.S.W.) in buffer solutions of pH 7 were rapidly inactivated by oxidizing agents (0.001

molar) which induced in the suspensions an oxidation-reduction potential of $+0.2$ volt or more. Oxidizing agents which induced a potential of $+0.1$ volt or less did not in general cause inactivation. A number of reducing agents (cystein, Na_2SO_3 , pyrogallate, $\text{Na}_2\text{S}_2\text{O}_4$, NaHS , platinized platinum $+ \text{H}_2$) protected the virus against the normal aerobic inactivation, cystein being particularly efficient as a protective agent. Mercuric chloride (0.001 M.) caused instantaneous inactivation and potassium cyanide (0.01 M.) had a protective action on the virus. By means of specially designed experiments it was shown that the inactivating effects observed were due to an action on the virus itself.

Parallel tests carried out with tobacco mosaic virus chiefly as a means of comparing it with T.S.W. virus are also recorded. These showed that tobacco mosaic virus was very resistant to those agents which inactivated T.S.W. virus.

52. D. B. Adam. Jour. Agric. Sth. Aust. 38: 939. 1935.

“Summary of Plant Disease Records in South Australia for the two years ending 30th June, 1934.”

53. D. B. Adam and T. T. Colquhoun. Jour. Aust. Inst. Agric. Sci. 2: 172. 1936.

“The Spread of Take-all through the Soil.”

Experiments are described to show that the spread of take-all through the soil is facilitated by the presence of the roots of susceptible plants. The extent of spreading is dependent to some degree on the closeness of planting. No spreading of infection occurred where wheat was planted at a distance of one foot from infected plants, whereas infection spread 20 in. along a row in which plants were two inches from infected plants and the same distance from one another in the row.

IV. INVESTIGATIONS ON ECONOMIC INSECTS.

(A) PASTURE AND CEREAL CROPS.

54. D. C. Swan. Jour. Agric. Sth. Aust. 37: 1149. 1934.

“A Scarab Beetle (*Aphodius tasmaniae* Hope) destructive to pastures in the South-East of South Australia.”

The numbers of this native insect have increased, particularly in the South-Eastern part of the State, following the development of permanent pastures and the associated increase in stocking. The larvae of this beetle burrow in the soil of pastures, favouring areas where dung has accumulated. The life cycle is briefly described, and some suggestions made regarding control measures.

55. J. Davidson. Jour. Agric. Sth. Aust. 38: 619. 1935.

“Control Methods used against Locusts and Grasshoppers.”

This paper describes briefly the habits of *Chortoicetes terminifera* Walk. and reviews the chief measures adopted in various countries for the control of locusts. The need for organization of control measures is stressed.

It is suggested that the use of the following poison bait is probably the method best suited to South Australian conditions.

Arsenite of Soda	$\frac{1}{2}$ lb.
Molasses	4 lb.
Bran	24 lb.
Water	$2\frac{1}{2}$ galls.

56. J. Davidson. Nature. 136: 298. 1935.

“Rainfall-Evaporation Ratio in relation to Locust and Grasshopper Outbreaks.”

The history of the 1934-35 locust outbreak in South Australia is given briefly. The distribution of *Chortoicetes terminifera* and its abundance are discussed with reference to climate and weather. The P/E ratio is used as an index of aridity and a map shows the areas and months in which the ratio P/E exceeds 0.5. The endemic areas for this species lie north of the 10 in. isohyet; an invasion of the southern agricultural areas takes place only when a favourable complex of seasons occurs.

57. H. G. Andrewartha. Jour. Agric. Sth. Aust. 39: 1233. 1936.

“Preliminary Survey of Far-North District as a Possible Endemic Area for Plague Grasshoppers.”

A survey trip through the Far-North pastoral district is described. It was found that *Chortoicetes terminifera* was present over the whole area shown in the map.

58. J. Davidson. Trans. Roy. Soc. Sth. Aust. 60: 1936.

“On the Ecology of the Black-tipped Locust (*Chortoicetes terminifera* Walk.) in South Australia.”

A widespread plague of locusts developed over the agricultural areas of South Australia during 1934 and 1935. The correct name for the species is *Chortoicetes terminifera* Walk. Previous outbreaks (probably of this species) had occurred in 1844, 1871 and 1890.

The immature stages and adults of *C. terminifera* are described and illustrated. The habits and biology of the species are described briefly. The physical environment in which *C. terminifera* lives in South Australia is described with reference to topography, rainfall, soil moisture, temperature and vegetation.

The history of the 1934-35 outbreak is given. Climate is important in limiting the endemic areas. Weather has an important influence on the abundance of the species and its ability to reach plague density in the invasion areas.

(B) ORCHARD AND MARKET GARDENS CROPS.

59. D. C. Swan. Jour. Agric. Sth. Aust. 38: 353. 1934.

“The Red-legged Earth Mite *Halotydeus destructor* Tucker, in South Australia, with remarks upon *Penthaleus major* Duges.”

Halotydeus destructor has been known as a pest of market crops in South Africa since 1907 and Western Australia since 1917. It has been known in South Australia since 1925, but has not been troublesome until the last few years. Details are given of its distribution, life history and habits in the field. It is active in the winter, dying out in the summer. The eggs are able to survive the summer and hatch again with the onset of the winter rains. The bionomics of the mite are discussed, and control methods surveyed. A discussion is also given of the related mite *Penthaleus major*, which frequents the same situations and has somewhat similar habits.

60. J. W. Evans. Jour. C.S.I.R. 7: 61. 1934.

“Thrips Investigation. 2. Some Factors that regulate the Abundance of *Thrips imaginis* Bagnall.”

Records of the numbers of *Thrips imaginis* in roses at Adelaide for the period from March 1932 to October 1933 are given. The data show a close correlation between the numbers that develop in the autumn and early spring. The abundance of *Thrips imaginis* is shown to be largely dependent upon weather.

61. H. W. Wheeler. Jour. C.S.I.R. 7: 70. 1934.

“Thrips Investigation. 3. Some Observations on the loss of Toxicity of Certain Dusts used in Experiments on the Control of the Apple Thrips *T. imaginis* Bagnall.”

Derris and pyrethrum were exposed to light and air for different periods. Their toxicity was then estimated both by chemical analysis and by tests with *Thrips imaginis*. It was found that the toxic constituents of derris decomposed more slowly than the pyrethrins.

62. H. G. Andrewartha and H. Vevers Steele. Jour. C.S.I.R. 7: 234. 1934.

“Thrips Investigation. 4. Some Observations on the Fluctuations in the Numbers of *Thrips imaginis* Bagnall in the Vicinity of Melbourne during the Period 1932-1934.”

Fluctuations in the numbers of *Thrips imaginis* in roses at Melbourne are recorded for the period September 1932 to July 1934. Attention is drawn to certain meteorological factors which appear to be associated with these fluctuations. Particular stress is placed upon the important rôle played by soil moisture in the preceding autumn in relation to the numbers which develop during the following spring.

63. H. G. Andrewartha. Jour. C.S.I.R. 7: 239. 1934.

“Thrips Investigation. 5. On the Effect of Soil Moisture on the Viability of the Pupal Stages of *Thrips imaginis* Bagnall.”

The influence of soil moisture on the viability of the pupal stages of *Thrips imaginis* is discussed. It was shown that there was a range of favourable soil moisture within which the viability did not vary; outside this range the viability fell away rapidly. The limits of the favourable range were not affected by temperature.

64. J. W. Evans. Jour. C.S.I.R. 8: 86. 1935.

“Thrips Investigation. 6. Further Observations on the Seasonal Fluctuations in Numbers of *Thrips imaginis* Bagnall and Associated Blossom Thrips.”

Curves showing the abundance of *Thrips imaginis*, *Haplothrips victoriensis*, and *Isoneurothrips australis* in roses at Adelaide are presented for the years 1932, 1933 and 1934. The abundance of *Thrips tabaci* in the flowers of Salvation Jane during the spring months of the same years is also given. While the first three indigenous species have shown a progressive decrease during this period the numbers of *Thrips tabaci*, an introduced insect, have increased.

65. H. G. Andrewartha. Jour. C.S.I.R. 8: 281. 1935.

“Thrips Investigation. 7. On the Effect of Temperature and Food upon Egg Production and the Length of Adult Life of *Thrips imaginis* Bagnall.”

Thrips imaginis adults, kept under conditions of uniform humidity laid no eggs below 8.5° C. At higher temperatures the total number of eggs laid was not affected by temperature but the rate of egg production was proportional to the temperature. Food was important in the production of eggs. Without pollen egg production did not proceed normally. When the leaf tissue of *Trifolium repens* or *Plantago lanceolata* was the only food available the length of life was reduced and no eggs were laid.

66. H. V. Andrewartha. Jour. C.S.I.R. 9: 57. 1936.

“Thrips Investigation. 8. The Influence of Temperature on the Rate of Development of the Immature Stages of *Thrips imaginis* Bagnall and *Haplothrips victoriensis* Bagnall.”

The immature stages of *Thrips imaginis* and *Haplothrips victoriensis* were reared at various constant temperatures under conditions of uniform humidity. The relationship between temperature and rate of development was expressed as a straight line for each species. The “zero of the velocity” curve and the thermal constant were determined in each case.

67. H. G. Andrewartha. Jour. Aust. Inst. Agric. Sci. 1: 78. 1935.

“The Prediction and Control of Outbreaks of *Thrips imaginis* Bagnall.”

Some of the factors that influence the abundance of *Thrips imaginis* are discussed. The importance of weather and food are stressed. The problem of control is an unusual one, consequently special types of insecticides will need to be developed.

68. J. Davidson. Jour. C.S.I.R. 8: 234. 1935.

“The Apple Thrips (*Thrips imaginis* Bagnall).”

The relation of weather to the number of *Thrips imaginis* present in the spring is discussed. The prospects of *Thrips imaginis* becoming numerous during the spring of 1936 in Western Australia, South Australia, Victoria, are discussed. Suggestions for control measures are advanced.

69. J. Davidson. Jour. Agric. Sth. Aust. 39: 930. 1936.

“The Apple Thrips (*Thrips imaginis* Bagnall) in South Australia.”

A brief account of the morphology and bionomics of *Thrips imaginis* is given. Fluctuations in the numbers of the insect are discussed. Suggestions for control measures are put forward.

70. H. Vevers Steele. C.S.I.R. Pamph. 54, 1935.

“Thrips Investigation: Some Common Thysanoptera in Australia.”

(c) MISCELLANEOUS.

- 71: D. C. Swan. Jour. Agric. Sth. Aust. 37: 1289. 1934.

“The Hay-itch Mite (*Pediculoides ventricosus* Newport) (*Acarina Pediculoididae*) in South Australia.”

A skin itch of agricultural workers resulting usually from the handling of stored hay is shown to be associated with the presence of a minute mite, *Pediculoides ventricosus*, in the material. This mite is shown to be

widespread in Australia. Details are given of the ecology of the mite; the various stages are illustrated. Suggestions for its control in hay stacks are given.

72. D. C. Swan. Med. Jour. Aust. 1934.

“Dermatitis caused by a Mite (*Pediculoides ventricosus*) and its Occurrence in Australia.”

A number of instances are recorded of a dermatitis of agricultural workers known to be caused by the mite *Pediculoides ventricosus*. Details of the biology of the mite, and of its relation to “hay itch” are given. A review is made of the literature relating to the condition in other parts of the world.

73. J. Davidson. Jour. Aust. Inst. Agric. Sci. 1: 105. 1935.

“Some aspects of Climate and Insect Ecology.”

The behaviour of an insect is influenced by the micro-climate of its ecological “niche”. It is important to establish correlations between weather factors and the biological responses of insects. It may be assumed that micro-climate in a local situation will react to weather in the area.

Temperature restricts the distribution of insects northwards and southwards in the two hemispheres; it also limits the activities of insects in the different seasons. Moisture restricts the geographic range and seasonal activity of insects.

Moisture zones in Australia have been plotted adopting the index of aridity of $P/E = 0.5$ and 1.0 respectively. These zones show close agreement with the distribution of native vegetation shown on Prescott’s Vegetation Map of Australia.

74. J. Davidson. Jour. Agric. Sth. Aust. 38: 998. 1935.

“Insects Observed on Crops in South Australia during the period June 1932 to June 1934.”

This paper deals briefly with the insect pests encountered from pasture and forage crops, field and market garden crops, fruit trees and grape vines, and on miscellaneous crops. Two pages of diagrams give the records of temperature and rainfall over monthly periods taken at eight stations typical of various climatic zones in South Australia, during the period under review.

75. H. V. Andrewartha and H. G. Andrewartha. Jour. C.S.I.R. 8: 289. 1935.

“A Multiple-Temperature Incubator.”

A home-made multiple-temperature incubator is described and illustrated. A short table of temperatures indicates the degree of accuracy which was obtained with the incubator.

76. D. C. Swan. Jour. Agric. Sth. Aust. 38: 1125. 1935.

“A Weevil attacking Mallow (*Malva parviflora* L. and *M. nicaeensis* All.) in South Australia.”

The various stages of *Ethemaia sellata* Pasc. are described and illustrated. Its biology is discussed briefly and photographs illustrate the nature of the damage it may occasionally do to *Malva*. It has not been found to feed on other than malvaceous plants.

77. J. Davidson. Trans. Roy. Soc. Sth. Aust. (in press).

“One Hundred Years of Entomology in South Australia.”

This paper formed the substance of a Centenary Address delivered to the Royal Society of South Australia on August 13, 1936. The general status of entomology in Europe in 1836 is discussed. The early history of entomology in South Australia seems to be associated mostly with the name of Charles Algernon Wilson, who arrived in South Australia in 1839. Prior to 1878 little development occurred in the science of entomology in South Australia. After this date many prominent names came to be associated with the science. A summary of the more important events, particularly with respect to applied entomology, is given.

78. D. C. Swan. Bull. Ent. Res. 27: 389. 1936.

“Berlese’s Fluid: Remarks upon its Preparation and use as a Mounting Medium.”

A modification of the formula is suggested by which a tendency for crystallization of this microscope mountant beneath the coverslip is avoided. Some details are given of its history, optical properties, and advantages as a mountant for small arthropods.

79. H. G. Andrewartha. Jour. Agric. Sth. Aust. 39: 1031. 1936.

“Some notes on Breeding Grounds of Plague Grasshoppers in South Australia.”

Two survey trips, one through the Gawler Ranges, the other in the North-East pastoral district, are described. A map shows the localities from which *Chortoicetes terminifera* was collected.

V. CLIMATOLOGY.

80. J. Davidson. Trans. Roy. Soc. Sth. Aust. 58: 33. 1934.

“The Monthly Precipitation-Evaporation Ratio in Australia, as determined by Saturation Deficit.”

The value of the P/E ratio (precipitation ÷ evaporation) as an index of the efficiency of precipitation in relation to moisture at the soil surface

month by month is discussed. The evaporation was calculated from records of saturation deficit. A map of Australia is given which shows the areas and months in which rainfall exceeds evaporation as determined by saturation deficit. It was concluded that the monthly P/E may be a useful single factor index for defining aridity in Australia month by month.

81. J. A. Prescott. *Trans. Roy. Soc. Sth. Aust.* 58: 48. 1934.

“Single Value Climatic Factors.”

The enumeration and examination of various attempts to calculate single values to represent climatic conditions allowing for the reduction of rainfall efficiency by temperature or evaporation. The factors of Lang (1915), de Martonne (1926), Emberger (1930), Thornthwaite (1931), McKibbin (1933) are based on rainfall and temperature only. Those of Transeau (1905) and Meyer (1926), based on rainfall and evaporation, are fundamentally more sound.

A satisfactory relationship between the evaporation from a free water surface and the saturation deficit of water vapour pressure is established for Australian evaporimeter stations. A series of maps of Australia illustrating mean annual values of certain climatic factors calculated according to recently published data are presented.

82. J. Davidson. *Trans. Roy. Soc. Sth. Aust.* 58: 197. 1934.

“Climate in Relation to Insect Ecology in Australia. 1. Mean Monthly Precipitation and Atmospheric Saturation Deficit in Australia.”

Certain meteorological data are important in studies of the distribution and abundance of certain insects; it is important to correlate changes in the physical environment and biological responses of the species.

Twelve charts show the average distribution of rain over Australia month by month. The isopleths given on the charts show the distribution of the mean values for the saturation deficit of the air month by month.

83. J. Davidson. *Trans. Roy. Soc. Sth. Aust.* 59: 107. 1935.

“Climate in Relation to Insect Ecology in Australia. 2. Mean Monthly Temperature and Precipitation-Evaporation Ratio.”

This is the second paper of a series. The value of the ratio of P/E (precipitation ÷ evaporation) on P/S.D. (precipitation divided by saturation deficit) as an index of soil moisture is discussed. The average monthly value $P/E = 0.5$ was adopted as the lower limit at which adequate moisture is available for plant growth. The moisture zones of Australia are given in twelve maps which also show the mean monthly isotherms.

84. J. Davidson. Trans. Roy. Soc. Sth. Aust. 60: 88. 1936.

“Climate in Relation to Insect Ecology in Australia. 3. Bioclimatic Zones in Australia.”

Rainfall, atmospheric humidity and temperature are the major climatic elements affecting the physical environment of animals and plants.

Australia has been mapped into zones in which these climatic elements have been assessed month by month. They have been referred to as “Bioclimatic zones”. The moisture zones have been assessed by means of selected values for the ratio monthly precipitation $\div$ monthly atmospheric saturation deficit at 235 stations in the Commonwealth; these values were converted into ratios for monthly precipitation $\div$ monthly evaporation (P/E). The temperature zones have been assessed on mean monthly and annual temperature values at the above stations.

The methods employed may be used to interpret the geographical range of particular animals and plants.

85. J. A. Prescott. Trans. Roy. Soc. Sth. Aust. 60: 93. 1936.

“The Climatic Control of the Australian Deserts.”

An examination of the monthly values of the ratio of rainfall to saturation deficiency and of the relationship of these values to soil moisture shows that a desert may be defined as an area in which, except for accidental periods, for none of the twelve months of the year does soil moisture reach the wilting point of plants.

In Australian areas where for any of the twelve months such values do not exceed 4 or 5, desert conditions may be expected.

86. E. A. Cornish. Quart. Jour. Roy. Meteor. Soc. 62: 481. 1936.

“On the Secular Variation of the Rainfall at Adelaide, South Australia.”

A detailed analysis of the rainfall of Adelaide, South Australia, has shown that throughout the 95 years, 1839–1933, there has been a definite oscillation with a period and amplitude of approximately 23 years and 30 days respectively, in the incidence and duration of the winter rains. Though small, the amplitude is approximately 20 per cent. of the length of the rainfall season. The total quantity precipitated has shown no statistically significant changes.

VI. MISCELLANEOUS.

87. A. E. V. Richardson. Pastoral Review 45: 1055 & 1167. 1935.

“The Problem of Soil Erosion in Pastoral Areas.”

This paper reviews the importance of the problem of soil erosion, its magnitude in South Australia, the causes of soil erosion in the semi-arid pasture areas and the mallee districts, together with a discussion of the possible methods of combating soil drift.

88. G. H. Clarke. Jour. Agric. Sth. Aust. 39: 1475. 1936.

“Important Weeds of South Australia.”

Nos. 19 and 20: Broad-leaved and Narrow-leaved Cotton Bushes (*Asclepias rotundifolia* Mill. and *A. fruticosa* L.).

The two weeds are illustrated by means of plates, one of which is coloured, showing full details as regards both vegetative and floral structure, as well as by a number of photographs depicting their general habits of growth. The accompanying descriptions deal in a popular manner with the systematics, floral structure, pollination mechanism, properties and uses, and methods of eradicating each of the two species.

89. A. E. V. Richardson. Proc. Roy. Geog. Soc. of Aust. (S.A. Branch) Centenary History of South Australia. 1936.

“Agricultural and Pastoral Progress.”

An account is given of the economic zoning of South Australia, and a review of the development and progress of the pastoral and agricultural and forestry industries of South Australia from their initial establishment up to the present time, together with an account of the major factors responsible for the progress.

90. J. C. M. Fornachon. Aust. Jour. Exp. Biol. & Med. Sci. 14: 215. 1936.

“A Bacterium causing ‘Disease’ in Fortified Wines.”

A bacterium has been isolated which is able to develop in wines containing 20 per cent. by volume of alcohol. The organism causes an increase in both fixed and volatile acidity. The optimum pH was found to be between 4 and 5, and the optimum temperature for growth in fortified wine about 23° C. The organism produces acid and gas from dextrose, levulose and sucrose, and converts portion of the levulose into mannite.

91. J. A. Prescott. Jour. Proc. Aust. Chem. Inst. (in press).

“The Chemist and the Farmer.”

Based on a Presidential Address to the South Australian Branch of the Australian Chemical Institute. An account of the historical development of the relationship between the chemist and the agricultural community, with special reference to the beginning of the agricultural chemical services in Australia.

92. A. E. V. Richardson. Adelaide Stock & Station Journal, 33: 1623, p. 3; 1624, p. 3. 1936.

“The Problem of Marginal Land.”

This paper is based on an address given before the Economic Society of Australia and New Zealand (S.A. Branch). The effect of price levels, production costs, improved technique, the business cycle and migration policies in the ebb and flow of marginal settlement are discussed, together with their application to marginal land problems in South Australia. Considerable adjustments of holdings in sub-marginal wheat areas appear to be inevitable. The higher rainfall zones of South Australia appear to offer the greatest possibilities for future agricultural development.

Meteorological Records, 1925-1935

Since the inception of the work of the Institute in 1925, daily records of rainfall, barometric pressure, maximum and minimum air temperature, atmospheric humidity, number of hours of bright sunshine, evaporation from a free water surface, and maximum and minimum soil temperatures at 1 inch, 6 inches, 12 inches, and 24 inches have been recorded. In addition, continuous records of air temperatures, atmospheric humidity, and soil temperatures have been taken.

In 1930 a self-recording anemometer, based on the Halliwell-Dines principle, was installed, and continuous records of the direction and velocity of the wind have been obtained.

RAINFALL.

Rainfall and its incidence are controlling factors in crop production. The average annual rainfall for eleven years, 1925-35, at the Waite Institute is 23·98 inches. The average annual rainfall for 96 years for Adelaide (four miles distant) is 21·1 inches. For the 1925-35 period the average rainfall at Adelaide was 21·14 inches.

A feature of the rainfall is its marked winter incidence. Approximately 77 per cent. of the annual precipitation occurs within the period of growth for cereals, May 1 to November 30. The summer months are characterized by hot, dry weather, low rainfall, and high rate of evaporation.

The climate is essentially of the Mediterranean type, with winter rainfall and summer drought. The dry period of summer and early autumn normally terminates early in May with a pronounced "break" in the weather. Antarctic rain systems set in in May, and continue more or less regularly till August. During this period the soil temperatures are low, but they never fall for any extended period below the temperature at which the growth of cereals is inhibited.

The rainfall averages $2\frac{3}{4}$ inches to 3 inches per month throughout the winter months, and the subsoil usually becomes thoroughly moist to an average depth of at least four feet. The growth of cereals proceeds slowly, and tillering is active during this period. Towards the end of August the air and soil temperatures rise substantially, and cereal crops and pastures make rapid growth. Transpiration becomes active, and as the crop approaches the stage of ear production (September-October) the rate of transpiration increases rapidly. The moisture supply of the soil begins to fall off rapidly with the increasing demands of the crop. During the period of earing the transpiration rate is often accelerated temporarily by hot northerly winds, which precede the easterly advance of the anti-cyclones.

Substantial rains in September or October are normally necessary for the production of heavy crops. A shortage of rainfall in these months leads to rapid deterioration of the crop, owing to rapid transpiration, brought about by a combination of high air temperatures and low atmospheric humidity. The growing crop adjusts itself to the environmental conditions by reducing the number of ear-bearing tillers. Cool weather experienced during this critical period, or during the ripening processes, materially lowers the transpiration rate and results in improved crop yields.

The harvesting period (December-January) synchronizes with hot, dry weather, which facilitates the harvesting of cereals, and enables grain of low moisture content and high quality to be produced.

The monthly rainfall for eleven years is summarized below.

Mean Monthly Rainfall for Eleven Years, 1925-35, Waite Institute.

Month.	Monthly Average, 1925-1932.	1933.	1934.	1935.	Monthly Average, 1925-1935.
January	0.485	1.219	0.576	0.859	0.594
February	1.278	0.404	0.139	0.026	0.981
March	0.821	1.425	0.722	2.671	1.035
April	1.626	2.091	1.483	1.924	1.682
May	3.176	6.849	0.058	2.916	3.202
June	3.561	1.799	1.140	2.858	3.117
July	3.440	2.192	1.180	3.220	3.101
August	3.062	3.854	4.899	3.245	3.318
September	2.766	3.709	4.051	2.857	2.976
October	1.757	0.681	2.497	2.619	1.805
November	0.904	0.259	3.793	0.920	1.109
December	1.135	0.423	1.528	0.634	1.060
Total	24.009	24.905	22.066	24.749	23.980

EVAPORATION.

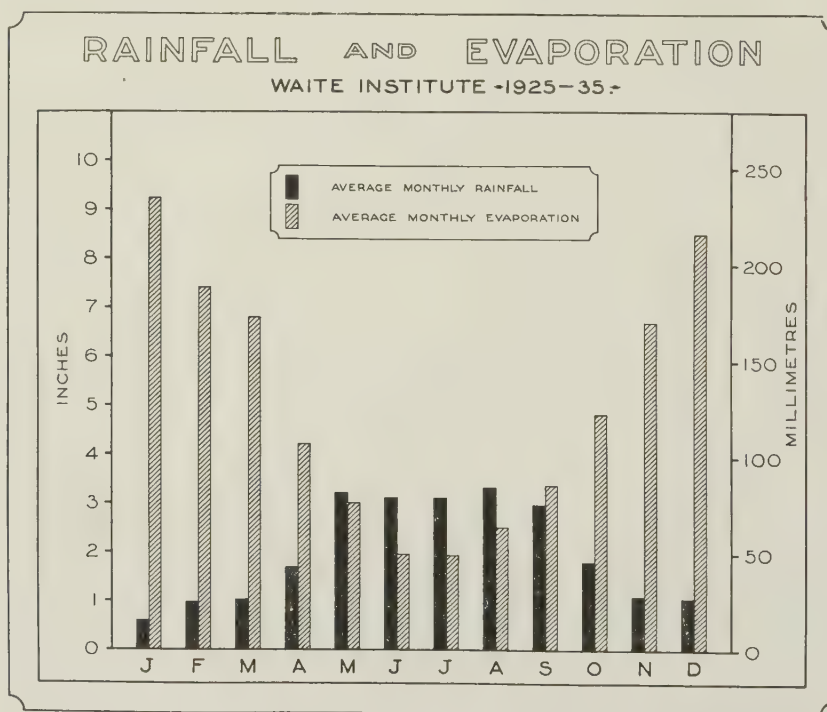
The evaporation rate is measured by the amount of loss of water from a freely-exposed water-surface at ground level. The apparatus used is a standard evaporimeter, 3 feet in diameter and 3 feet deep, enclosed within a cylindrical tank, 4 feet in diameter and 3 feet deep. Both tanks are sunk to ground level and filled within 2 inches of the surface. The evaporation is measured by the fall of the surface level of the water in the inner tank. A large glass float attached to a brass rod registers the surface level of the water, and a vernier attachment enables the fall of the water surface to be recorded to the nearest $\frac{1}{1000}$ th of an inch.

A summary of the monthly evaporation from a free water surface for eleven years, 1925-1935, is given below:

*Mean Monthly Evaporation Rate from a Free Water Surface, Waite Institute,
1925-35.*

Month.	Monthly Average, 1925-1932. (inches).	1933. (inches).	1934. (inches).	1935. (inches).	Monthly Average, 1925-1935. (inches).	Daily Evaporation Average. (inches).
January	9.533	7.854	10.168	7.242	9.230	0.298
February	7.452	7.748	7.224	6.828	7.401	0.262
March	6.764	6.432	7.559	6.579	6.790	0.219
April	4.405	4.332	3.686	3.126	4.217	0.140
May	3.177	2.630	3.164	2.249	3.042	0.098
June	1.939	1.932	2.196	1.910	1.959	0.065
July	1.932	1.924	2.132	1.720	1.930	0.062
August	2.583	2.108	2.201	2.540	2.501	0.081
September	3.366	3.128	4.036	3.036	3.375	0.112
October	4.900	4.939	4.477	4.509	4.830	0.155
November	6.840	6.674	6.184	6.205	6.708	0.223
December	8.753	8.008	7.160	8.198	8.490	0.274
Total	61.644	57.709	60.187	54.142	60.473	0.166

The mean annual evaporation from a free water surface is 60.47 inches per annum. During the period of crop growth (May to November inclusive) the evaporation is 24.34 inches, or 40 per cent. of the annual evaporation.



Mean monthly rainfall and evaporation, Waite Institute, 1925-35.

The average evaporation rate is an important factor in determining the efficiency of the rainfall for crop production, mainly because of the close correlation that has been shown to exist between the rate of transpiration from the crop and the rate of evaporation from a free water surface. The rate of evaporation may be regarded as an expression of the sum of the environmental factors—radiation intensity, air temperature, wet bulb depression, and wind velocity—all of which influence the rate of transpiration of the crop.

Whilst the ratio, annual evaporation to annual rainfall, is 2·6 to 1, the ratio of evaporation to rainfall for the normal period of crop growth is less than 1·3 to 1. The mean monthly rainfall and evaporation rate are shown graphically in the accompanying graph. From May to September the mean rainfall exceeds the total evaporation from a free water surface, and the conditions for the growth of pastures and cereals are very favourable. During October and November, however, the mean evaporation rate is 4 times greater than the mean rainfall for these months. This high ratio of evaporation to rainfall at the critical period of development of the cereal crop is the main limiting factor to heavy crop yields.

AIR TEMPERATURES.

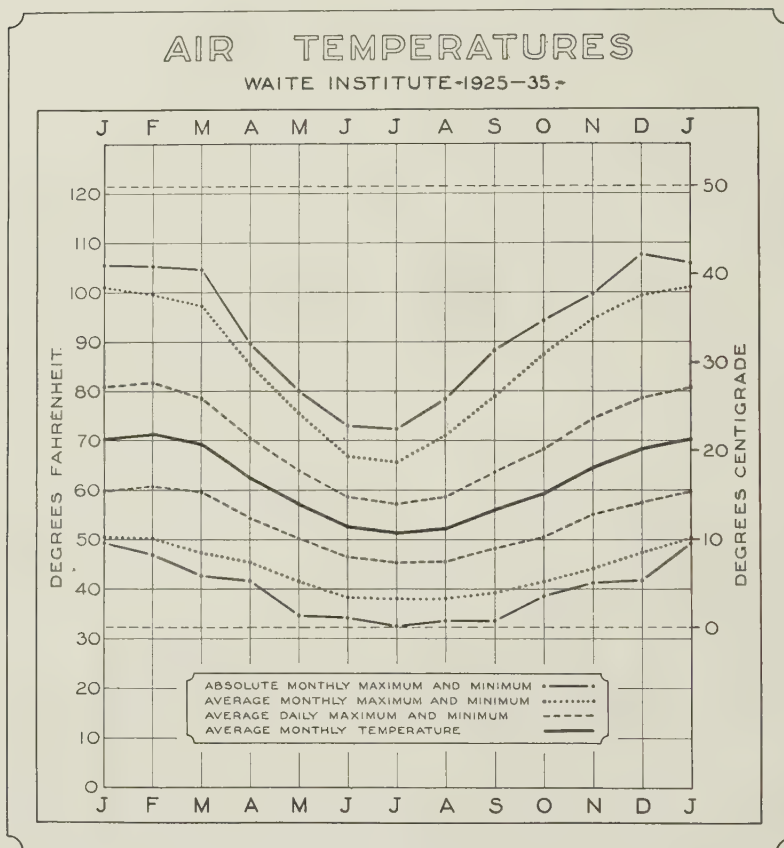
Mean air temperature is an important factor in determining the climate of a region. Plant life is constantly under the influence of the temperature of the air near the surface of the earth. The mean air temperature and its daily and seasonal fluctuations during the rainy season largely determine the types of crop that can be grown under given soil and rainfall conditions.

The air temperatures are obtained from standard maximum and minimum thermometers shielded from the direct rays of the sun in a standard meteorological screen in such a manner as not to obstruct atmospheric circulation. The significance of the mean daily air temperature depends upon the amplitude of the periodic daily range and the nature of the variations from day to day. The daily minimum temperature usually occurs immediately prior to sunrise, and the daily maximum between 2 and 3 p.m. The average of the daily maximum and minimum for each month gives the mean monthly maxima and minima.

The significance of the mean monthly temperature depends upon the extent of the periodic variation in the daily values from which it is derived, and the extent of the accidental fluctuations that occur during the month. In addition to the average of the daily maxima, and the average of the daily minima, it is important to know the mean of the monthly extremes and the absolute maximum for each month. These data are summarized in the accompanying graph, which shows for a period of eleven years, 1925–35, the following values:

- (a) The mean monthly air temperature in degrees Fahrenheit and Centigrade.
- (b) The mean daily maximum and mean daily minimum air temperatures.

- (c) The mean monthly maximum and minimum air temperatures, i.e. the mean of the highest and lowest temperatures recorded each month.
- (d) The absolute monthly maximum and minimum air temperatures, or the highest or lowest temperatures ever recorded in each month.



Absolute and mean monthly and daily air temperatures, Waite Institute, 1925-35.

The vertical distance between the lines showing the mean daily maxima and minima represents the average daily range in temperature for each month. Similarly, the distance between the lines showing the mean monthly maxima and minima shows the average monthly range, whilst the distance between the absolute monthly maxima and minima shows the extent of the range in absolute monthly temperatures.

The mean air temperature during the growing period of the crop (May-November) is 56.2°F. , or 13.4°C. The mean monthly maximum and minimum air temperatures during this period are respectively 63.6°F. and 48.8°F.

*Mean Monthly Maximum and Minimum Air Temperatures for Eleven Years,
1925-35, Waite Institute.*

Month.	Monthly Average 1925-1932.		1933.		1934.		1935.		Monthly Average 1925-1935.	
	Max. °F	Min. °F	Max. °F	Min. °F	Max. °F	Min. °F	Max. °F	Min. °F	Max. °F	Min. °F
January	81.1	59.7	76.5	58.4	85.5	64.5	79.1	57.2	80.9	59.8
February	81.6	60.7	83.1	60.1	83.3	62.1	80.5	60.4	81.8	60.7
March	78.3	59.1	76.0	56.7	84.5	65.9	77.5	61.3	78.6	59.7
April	71.4	54.5	69.9	52.5	67.7	53.4	68.1	54.7	70.6	54.2
May	63.7	50.1	62.8	50.0	69.8	52.2	61.6	49.0	64.0	50.2
June	58.5	46.2	60.7	47.9	61.1	47.8	57.8	47.1	58.8	46.6
July	56.9	45.2	57.4	43.4	60.5	48.1	57.6	46.2	57.3	45.4
August	58.7	45.3	57.1	45.2	58.9	46.5	61.6	48.6	58.8	45.7
September	63.5	48.1	62.0	47.8	65.7	49.7	64.6	49.5	63.7	48.3
October	67.8	50.1	71.1	50.5	67.7	51.0	69.3	52.8	68.2	50.5
November	74.7	55.0	74.2	54.6	72.5	54.9	74.7	56.3	74.4	55.1
December	79.0	57.5	77.8	56.9	78.1	57.3	79.2	58.7	78.8	57.5
Mean	69.6	52.6	69.1	52.0	71.3	54.5	69.3	53.5	69.7	52.8

SOIL TEMPERATURES.

The maximum and minimum soil temperatures are recorded at 1 inch, 6 inches, 12 inches, and 24 inches under the surface of the land kept in fallow. Records of soil temperature in the surface layers of soil are of considerable importance in studying the biological activities of the soil, particularly the process of nitrification and the relationship of temperature to such activities. The records are taken by Negretti and Zambra self-recording soil thermometers, which give continuous records of the fluctuations in soil temperature.

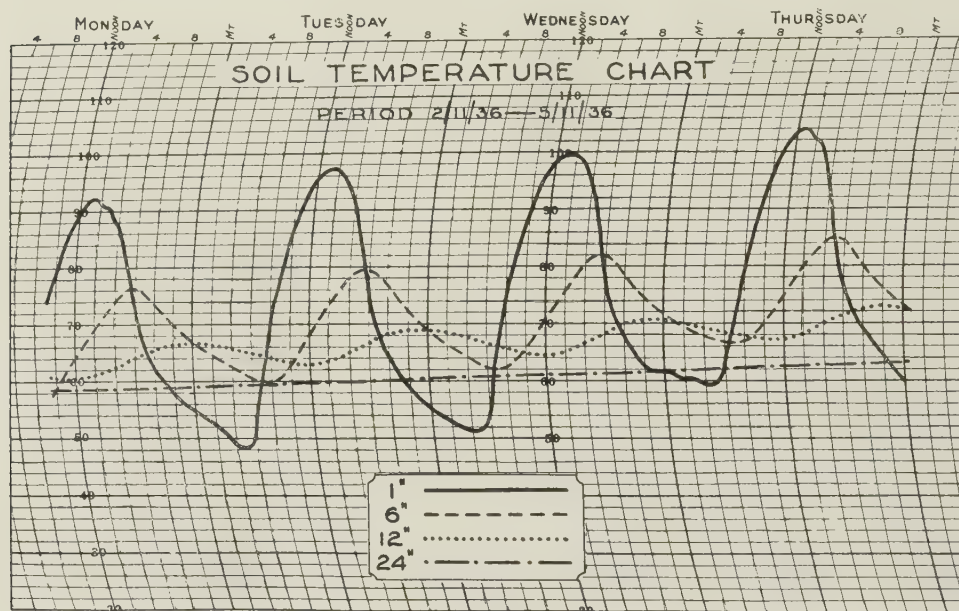
The mean monthly maximum and minimum soil temperatures for eleven years are summarized in the following table:

*Mean Monthly Soil Temperatures at 1 inch, 6 inches, 12 inches, and 24 inches, for
Eleven Years, 1925-35.*

Month.	At 1"		At 6"		At 12"		At 24"	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	112.5	65.6	86.1	72.9	78.1	72.4	75.5	71.4
February	109.4	65.3	85.1	72.4	77.5	72.0	75.9	72.1
March	102.2	63.3	80.7	69.7	74.7	67.8	74.5	70.6
April	85.4	56.7	70.4	61.7	67.0	62.9	68.8	65.0
May	72.8	51.5	61.7	54.8	60.1	56.6	62.5	59.5
June	65.5	48.5	56.6	51.3	55.1	52.1	57.4	54.9
July	63.3	47.3	54.7	49.7	53.2	50.1	55.0	52.6
August	66.6	48.3	56.9	51.2	53.9	50.6	55.2	52.4
September	74.9	51.5	62.8	55.1	58.5	54.4	58.4	55.4
October	84.9	55.5	69.6	59.8	63.7	59.0	62.8	59.5
November	98.9	60.9	78.5	65.9	70.6	65.2	68.5	64.8
December	108.6	64.2	84.1	70.7	75.4	69.7	73.0	69.1

The march of soil temperature is determined primarily by solar radiation. At depth, the soil for all practical purposes has a constant temperature. The surface layers, however, show wide daily, monthly, and annual fluctuations. The surface layer of soil (1 inch) shows considerable fluctuations in temperature, since during the day a considerable amount of radiant heat is received from the sun, and during the night the surface layers of soil lose heat rapidly by radiation.

Records show that during a typical week during mid-summer the temperature of the surface 1 inch of soil gave a daily fluctuation of 50°F. to 60°F. At 6 inches deep the daily fluctuation was $10\text{--}14^{\circ}\text{F.}$ during the same period. During a typical week in mid-winter the daily fluctuation at 1 inch did not exceed 18°F. , and at 6 inches the daily variation was less than 6°F.



Graph showing daily fluctuation in soil temperature at depths of one inch, six inches, one foot and two feet, Waite Institute, 1936.

The mean monthly minimum soil temperature does not at any period of the year fall below the temperature at which germination or growth of cereals is inhibited (41°F.).

The time of the maximum soil temperature varies with the depth. At the soil surface the time of maximum temperature is, on clear days, determined by the time at which the sun is on the meridian. Since this is practically constant throughout the year, the time at which the maximum temperature of the surface soil is reached is also constant. The temperature wave is transmitted by conduction

from the surface layer to the successive soil layers below the surface. The rate of conduction is slow, hence the time of maximum temperature at the lower layers will show a lag behind that of the maximum temperature at the surface.

Throughout the year, on clear days, when radiation intensity is at a maximum, the maximum temperature of the soil at 1 inch deep is reached at about 1.30 p.m., whilst air temperatures recorded in an adjacent meteorological screen reach a maximum between 2.30 and 3 p.m. The maximum temperature of the soil at a depth of 6 inches below the surface occurs at approximately 5.30 p.m.

On the other hand, the time of minimum soil temperature varies with the season. The minimum at the surface of the soil is reached normally just before sunrise, i.e. just before solar radiation begins to affect air and soil temperatures. The actual time of this minimum soil temperature will depend upon the time of sunrise. Since the time of the minimum soil temperature at the surface varies, so the time of the minimum soil temperature below the surface will vary.

During January the minimum temperature at 1 inch occurs at 5 a.m., and 6 inches about 8 to 8.30 a.m. During July the minimum temperature at 1 inch is reached at 7.30 a.m., and at 6 inches shortly after 10 a.m.

The maximum temperature of the surface of the soil is invariably higher than that of the maximum air temperature. The differences between the maximum air temperature and the maximum temperature at the surface of the soil are much less marked in winter than in summer.

The mean monthly amplitude of the daily temperature waves in soil and air for eleven years is summarized in the following table.

*Monthly Means of Amplitudes of Daily Temperature Waves in Soil and Air,
1925-35.*

Month.	Soil temperature.			Air Temperature.
	1"	6"	24"	
January ..	46.9	13.2	4.1	21.1
February ..	44.1	12.7	3.8	21.1
March ..	38.9	11.0	3.9	18.9
April ..	28.7	8.7	3.8	16.4
May ..	21.3	6.9	3.0	13.8
June ..	17.0	5.3	2.5	12.2
July ..	16.0	5.0	2.4	11.9
August ..	18.3	5.7	2.8	13.1
September ..	23.4	7.7	3.0	15.4
October ..	29.4	9.8	3.3	17.7
November ..	38.0	12.6	3.7	19.3
December ..	44.4	13.4	3.9	21.3

The amplitude of the daily temperature waves in soil varies according to season and depth. Thus for January the mean daily variation in soil temperature at 1 inch is 46.9° F., at 6 inches 13.2° F., and at 24 inches 4.1° F. In July the

mean daily variation is only 16.0° F. at 1 inch, 5.0° F. at 6 inches, and 2.4° F. at 24 inches. The amplitude of the daily temperature wave in air is for January 21.1° F., and for July 11.9° F.

It will be noted that during the winter months the mean minimum soil temperature increases from 1 inch to 24 inches. At a depth of 24 inches the minimum soil temperature exceeds 52° F. throughout the winter months, whilst the minimum soil temperature at 1 inch falls to 47.3° F. in July. This probably explains why early-sown crops under favourable conditions of moisture supply frequently make such vigorous rank growth during the winter months as to necessitate feeding down by stock. The root systems of early-sown crops become well established in the subsoil, and the higher soil temperatures of the lower layers are favourable for active growth.

NUMBER OF HOURS OF BRIGHT SUNSHINE.

The number of hours of bright sunshine is recorded daily by means of a Campbell-Stokes sunshine recorder and summarized in the following table.

Mean Number of Hours of Bright Sunshine per Month and per Day for Eleven Years, 1925-35, Waite Institute.

Month.	Number of hours per day.		Number of hours per month.
January	9.0		280
February	8.7		245
March	7.2		223
April	5.7		171
May	4.3		134
June	3.4		103
July	3.4		105
August	4.4		136
September	5.7		172
October	6.6		205
November	8.2		246
December	8.8		272
	6.2		2,292

The total number of bright sunshine hours per annum is 2,292, or a daily average throughout the year of 6.2.

WIND VELOCITY.

Continuous records both of the velocity of the wind and its direction have been registered by a self-recording anemometer since 1931. The average daily maximum wind velocity and the daily average velocity in miles per hour during each month of 1931-35 are summarized below.

*Average Daily Maximum and Daily Average Wind Velocity (in miles per hour)
for years 1931-35, Waite Institute.*

Month.	1933.		1934.		1935.		1931-1935.	
	Av. Daily Max.	Daily Av.	Av. Daily Max.	Daily Av.	Av. Daily Max.	Daily Av.	Av. Daily Max.	Daily Av.
January	23	4.0	27	4.9	24	3.1	25	4.6
February	22	4.4	23	3.7	21	3.3	23	4.1
March	23	4.7	21	2.8	22	4.1	22	4.0
April	21	2.8	22	2.7	19	2.8	20	3.0
May	17	2.9	14	1.0	14	2.0	16	2.3
June	12	1.4	18	2.3	16	2.7	16	2.6
July	17	2.3	19	2.8	20	4.8	18	3.0
August	16	2.5	22	3.3	21	5.2	19	3.7
September	17	3.3	24	4.6	21	4.6	20	3.9
October	24	3.9	23	4.0	22	4.6	23	4.3
November	28	5.0	22	4.0	24	5.9	24	4.7
December	24	3.9	14	2.6	26	5.7	22	4.3
	20.3	3.4	20.8	3.2	20.8	4.1	20.7	3.7

Records of Field Experimental Work
1925-1935

Records of Field Experimental Work, 1925-35

NOTE ON THE SOIL OF THE EXPERIMENTAL FIELD.

The surface (0-4 inches) soil of the area on which the major part of the experimental work has been conducted is a brown loam moderately high in silt and in fine sand, and containing a small amount of calcium carbonate. It becomes slightly heavier between 4-9 inches, though essentially the same in type. The immediate subsoil is a light red-brown medium clay, showing a sharp increase in clay content to 47 per cent., again with only a trace of calcium carbonate.

Increasing clay content and heavier texture occur to 3 feet, at which there is a reversion to a light clay, with a definite rise in calcium carbonate to approximately 4 per cent.

The reaction is weakly acid at the surface, becoming approximately neutral in the heavy clay horizon, and rising to above pH 8 with the advent of calcium carbonate. The mechanical analysis, description, and some chemical data of a profile are included in the following table.

Sample No.	U151	U152	U153	U154	U155	U156	U157
Depth in inches.	0-4	4-9	9-18	18-27	27-36	36-45	45-54
Coarse sand	2.1	1.9	1.2	0.7	0.6	0.8	1.3
Fine sand	43.7	40.8	26.3	18.6	19.2	24.5	25.3
Silt	34.8	33.8	22.8	18.8	19.3	28.4	29.7
Clay	18.0	21.8	47.4	59.9	59.2	40.7	37.2
Loss on acid treatment	1.0	0.7	1.1	1.4	1.6	6.3	5.2
Moisture	0.4	0.6	1.2	2.0	1.7	1.2	1.1
Loss on ignition ..	4.4	4.1	6.2	7.3	7.2	7.3	6.7
CaCO ₃	0.03	Trace	0.01	—	0.13	4.8	4.0
Nitrogen	0.10	0.09	0.08	0.08	0.07	0.05	0.04
Reaction pH	5.9	5.9	6.4	6.4	6.9	8.2	8.3
Soil Description ..	Brown loam	Brown loam to clay loam	Light red brown medium clay	Red brown heavy clay	Brown heavy clay	Brown light clay	Brown light clay

SUMMARY OF FIELD EXPERIMENTS.

1. Permanent Rotation Tests, 1925-35.
2. Manurial Tests with Wheat, Oats, Barley, 1925-35.
3. Sulphate of Ammonia on Wheat after Stubble and Fallow.
4. Equivalent quantities of Nitrogen on Wheat.
5. Sulphate of Ammonia on Oats.
6. Sulphate of Ammonia on Barley.
7. Varietal response of Wheat to Superphosphate and Nitrogen.
8. Superphosphate and Nitrogen on Wheat grown in rotation.
9. Superphosphate and Varying Seed Rates on Canary Grass.
10. Nitrogen, Superphosphate and Lime on Wheat after Fallow.
11. Nitrogen, Superphosphate and Lime on Barley after Wheat.
12. Nitrogen, Superphosphate and Lime on Oats after Barley.
13. Top-dressing of Natural Pastures with equivalent dressings of various forms of Phosphate.
14. Yield of a Seeded Pasture under different systems of management.
15. Phosphorus and Nitrogen on the Yield and Botanical Composition of two swards.
16. Sulphate of Ammonia on Seeded Pasture, Mount Barker, 1933-35.
17. Establishment of Pasture with varying Cover Crops and Fertilizer Treatments, Tintinara.
18. Effect of Superphosphate on Subterranean Clover.
19. Yield Trials of New Crossbred Wheats—Waite Institute, 1933.
20. Yield Trials of New Crossbred Wheats—Waite Institute, 1934.
21. Yield Trials of New Crossbred Wheats—Waite Institute, 1935.
22. Yield Trials of New Crossbred Wheats—Yurgo, 1935.

A NOTE ON THE USE AND CONSTRUCTION OF THE SUMMARY TABLES.

Yields of grain in bushels per ac. Mean of all varieties ± 1.281 .

Superphosphate.	Sulphate of ammonia			Mean	Increase
	N ₀	N ₁	N ₂	± 0.740	± 1.047
P ₀	42.14	41.74	43.28	42.39	—
P ₁	47.39	49.96	52.30	49.89	+7.50
P ₂	50.23	52.05	53.85	52.04	+2.15
Mean ± 0.740	46.59	47.92	49.81	48.11	—
Increase ± 1.047	—	+1.33	+1.89		

In this table, and others of a like nature, the numbers in ordinary type are the mean yields of the treatments indicated at the headings of the columns and the left-hand margins of the rows. Thus 49.96 is the yield in bushels per ac., averaged over all three varieties and all plots receiving 97 lb. per ac. of superphosphate plus 100 lb. per ac. of sulphate of ammonia. The numbers in heavy type denote more general averages. Thus, 42.39 is the yield in bushels per ac., averaged over all varieties and all nitrogenous treatments, of the plots without superphosphate. The general mean of all treatments is 48.11 bushels per ac. The numbers in italics preceded by a + sign denote increases, while those with a — sign denote decreases. Thus the average response to the first dressing of superphosphate is 7.50 bushels per ac., and the additional response due to the second dressing of superphosphate is 2.15 bushels per ac.; whence the average increase in favour of the second dressing over no superphosphate is 9.65 bushels per ac.

The standard errors (prefaced by the sign $\pm$) applicable to all comparisons of likely interest are given in the tables. As a rough rule, it may be taken that a quantity is significant if it exceeds twice its standard error. Thus the mean increase due to the first dressing of superphosphate is 7.50 ± 1.047 , and being over seven times its standard error, it is significant. In the same way, the additional response to the second dressing is 2.15 ± 1.047 and is therefore just significant. On the other hand, the average increase due to the first dressing of nitrogen, 1.33 ± 1.047 , is insignificant; neither is the additional response to the second dressing significant, but the increase over no nitrogen, i.e. 3.22, is significant.

In testing the difference between two quantities with the same standard error, it may be assumed that their difference is significant if it exceeds three times that standard error. Thus the difference between 7.50 and 2.15 is 5.35, and since this exceeds three times 1.047, there is a significant drop in the response to the higher dressing of superphosphate.

1. PERMANENT ROTATION TESTS.

Objective:

To determine the yield of wheat when grown under different systems of crop rotation.

Technique:

- (1) Thirty-one plots, grouped in 12 rotations, with wheat grown in each rotation every year.
- (2) Size of each plot = 0.144 acre.
- (3) Basal manurial dressing with each sown crop 20 lb. P_2O_5 per acre 1925-28, 40 lb. P_2O_5 (= 187 lb. super), 1929-35.
- (4) Varieties of crop: wheat, Sepoy; oats, Early Burt; barley, Pryor; peas, Brunswick White; pasture, Wimmera rye-grass.

Mean Yields for Seasons 1926-35.

Crop Rotation.		Wheat (bush. per ac.).	Oats (bush. per ac.).	Barley (bush. per ac.).	Peas. (bush. per ac.).	Temporary Pasture (cwt. per acre of dry hay).
1.	Wheat, bare fallow	35.37	—	—	—	—
2.	Wheat, peas	29.03	—	—	17.57	—
3.	Wheat, pasture, bare fallow	38.97	—	—	—	28.30
4.	Wheat, oats, bare fallow ..	37.64	52.61	—	—	—
5.	Wheat, peas, fallow	39.21	—	—	26.16	—
6.	Wheat, barley, fallow ..	38.19	—	51.71	—	—
7.	Wheat continuously . . .	17.03	—	—	—	—
8.	Wheat, oats, peas	32.74	45.61	—	25.38	—
9.	Wheat, barley, peas . . .	34.02	—	48.46	25.85	—
10.	Wheat, oats, pasture, bare fallow	44.38	59.87	—	—	32.93
11.	Wheat, Sudan grass . . .	36.69	—	—	—	12.30
12.	Wheat, bare fallow	38.97	—	—	—	—

2. MANURIAL TESTS WITH WHEAT, OATS AND BARLEY.

Objective:

To determine the effect of various fertilizers on the yield of wheat, oats and barley.

Technique:

- (1) Plots not replicated, but each group sown in duplicate from 1929 onwards with six unmanured controls.
- (2) Size of each plot = $\frac{1}{30}$ th acre.
- (3) Wheat sown on fallow 1927–29, peas 1930, barley stubble 1931, fallow 1932–34.
- (4) Oats sown on fallow 1927–28, and wheat or barley stubble in other years.
- (5) Barley sown on oats or wheat stubble.

Mean Yields Seasons 1925–34.

Dressing of fertilizer.						Wheat (bush. per ac.).	Oats (bush. per ac.).	Barley (bush. per ac.).
1. Effect of Superphosphate:								
No manure	..	..	..	..	..	25·94	55·18	36·05
10 lb. P_2O_5 (47 lb. super)	..	..	..	..	..	34·99	59·67	45·64
20 lb. P_2O_5 (94 lb. super)	..	..	..	..	..	37·24	60·52	48·24
30 lb. P_2O_5 (140 lb. super)	..	..	..	..	..	38·73	61·52	49·88
40 lb. P_2O_5 (187 lb. super)	..	..	..	..	..	39·02	59·73	50·80
60 lb. P_2O_5 (280 lb. super)	..	..	..	..	..	39·46	61·13	51·45
2. Equivalent dressings of Phosphate:								
No manure	..	..	..	..	..	25·94	55·18	36·05
Superphosphate 94 lb. (= 20 lb. P_2O_5)	..	..	..	..	..	37·24	60·52	48·24
Basic Slag 129 lb. (= 20 lb. P_2O_5)	..	..	..	..	..	36·41	59·06	48·57
Bonedust 109 lb. (= 20 lb. P_2O_5)	..	..	..	..	..	32·44	58·86	44·79
3. Lime as a Supplement:								
Superphosphate 94 lb. (= 20 lb. P_2O_5)	..	..	..	..	..	37·24	60·52	48·24
Superphosphate 94 lb. (20 lb. P_2O_5) + lime, 20 cwt. every 4 years	..	..	..	..	..	40·60	60·89	55·32
4. Nitrogen:								
Superphosphate 94 lb. (= 20 lb. P_2O_5)	..	..	..	..	..	37·24	60·52	48·24
Superphosphate 94 lb. (= 20 lb. P_2O_5) + nitrate of soda 78 lb. (= $12\frac{1}{2}$ lb. N)	..	..	..	..	..	38·43	64·33	54·35
Superphosphate 94 lb. (= 20 lb. P_2O_5) + sulphate of ammonia 60 lb. (= $12\frac{1}{2}$ lb. N)	..	..	..	..	..	39·22	62·21	54·10

3. SULPHATE OF AMMONIA ON WHEAT AFTER STUBBLE AND AFTER FALLOW.

Treatments:

- A. No nitrogen.
- B. Sulphate of ammonia, $\frac{1}{2}$ cwt. at seeding.
- C. Sulphate of ammonia, 1 cwt. at seeding.
- D. Sulphate of ammonia, 2 cwt. at seeding.
- E. Sulphate of ammonia, 1 cwt. in spring.
- F. Sulphate of ammonia, 1 cwt. at seeding and 1 cwt. in spring.

Technique:

- a. Thirty-six plots, each $\frac{1}{25}$ th acre, after fallow and 36 after stubble.
- b. Six treatments with six replications in the form of a Latin square.
- c. Basal dressing of 288 lb. superphosphate applied at seeding to all wheat plots in year of the test.
- d. Samples for soil moisture and nitrate nitrogen taken on no nitrogen plots after stubble and fallow.

Effect of Various Quantities of Sulphate of Ammonia on Yield of Wheat (Total Produce and Grain) when grown after (a) Bare Fallow, (b) Wheaten Stubble (Stubble-ploughed land), Waite Institute, 1928-32.

Quantities of Sulphate of Ammonia.	Total Produce. (cwt. per ac.).		Grain. (bush. per ac.).	
	Mean Yield 1928-32.	Increase due to Nitrogen.	Mean Yield 1928-32.	Increase due to Nitrogen.
Grown after Stubble:				
A. No nitrogen . .	47.5	—	36.56*	—
B. $\frac{1}{2}$ cwt. at seeding	52.7	5.2	39.72	3.16
C. 1 cwt. at seeding	57.4	9.9	41.95	5.39
D. 2 cwt. at seeding	66.5	19.0	45.69	9.13
E. 1 cwt. in spring .	55.1	7.6	40.50	3.94
F. 1 cwt. at seeding, 1 cwt. in spring .	64.8	17.3	45.07	8.51
Grown after Fallow:				
A. No nitrogen . .	70.3	—	49.09†	—
B. $\frac{1}{2}$ cwt. at seeding	73.3	3.0	50.58	1.49
C. 1 cwt. at seeding	74.3	4.0	50.47	1.38
D. 2 cwt. at seeding	75.8	5.5	49.77	0.68
E. 1 cwt. in spring .	73.0	2.7	49.46	0.37
F. 1 cwt. at seeding, 1 cwt. in spring .	75.2	4.9	49.28	0.19

*The standard error of the difference between any two mean values for 1928-32 is 1.47 bushels per acre.

†The standard error of the difference between any two mean values for 1928-32 is 1.03 bushels per acre.

4. EQUIVALENT DRESSINGS OF NITROGEN ON WHEAT.

Treatments:

Nitrogenous fertilizers applied at the rate of 23 lb. nitrogen per acre.

- A. No nitrogen.
- B. Nitrate of Soda, 150 lb. per acre.
- C. Sulphate of Ammonia, 112 lb. per acre.
- D. Nitro-chalk, 150 lb. per acre.
- E. Urea, 50 lb. per acre.
- F. Diammonium phosphate, 112 lb. per acre.

Technique:

- a. Thirty-six plots, each $1/25$ th acre, consisting of six treatments and six replications randomized in the form of a Latin square.
- b. Basal dressing of 288 lb. of superphosphate applied to all plots except those receiving diammonium phosphate.
- c. Diammonium phosphate broadcast on surface after seeding in 1928, before seeding in 1929, and drilled in with seed in subsequent years.
- d. Plots sown on land ploughed from natural pasture in 1928 and from land previously cropped with wheat in subsequent years.

Effect of Equivalent Quantities of Nitrogen (23.4 lb. per acre) applied in the form of Nitrate of Soda, Sulphate of Ammonia, Nitro-chalk, Urea and Diammonium Phosphate, on the Yield of Wheat (Total Produce and Grain) after Pasture or Wheat, Waite Institute, 1928-32.

Treatments. Nitrogen Fertilizer at rate 23.4 lb. Nitrogen per acre.	Total Produce (cwt. per ac.).		Grain (bush. per ac.).	
	Mean Yield 1928-32.	Increase due to Nitrogen.	Mean Yield 1928-32.	Increase due to Nitrogen.
A. No nitrogen	33.02	—	27.99	—
B. Nitrate of Soda	45.50	12.48	35.62	7.63
C. Sulphate of Ammonia . .	42.67	9.65	33.77	5.78
D. Nitro-chalk	43.35	10.33	34.12	6.13
E. Urea	42.00	8.98	33.14	5.15
F. Diammonium Phosphate	39.23	6.21	30.82	2.83

Treatment is significant; the standard error of a difference between the mean values of grain for 1928-32 is 0.81 bushels per acre.

5. SULPHATE OF AMMONIA ON OATS.

Variety: Early Burt; 60 lb. per ac. sown on wheat stubble.

Basal dressing of 2 cwt. per ac. superphosphate.

Treatments:

- A. No nitrogen.
- B. $\frac{1}{2}$ cwt. sulphate of ammonia at seeding.
- C. 1 cwt. sulphate of ammonia at seeding.
- D. 2 cwt. sulphate of ammonia at seeding.
- E. 3 cwt. sulphate of ammonia at seeding.
- F. 1 cwt. sulphate of ammonia in spring.

Design: Treatments arranged in a Latin square.

Area of plot = 1/25th acre.

Yields of grain in bushels per ac.

Year.	Treatment					
	A	B	C	D	E	F
1933	34.58	43.49	55.13	77.65	85.16	54.27
1934	47.24	56.87	64.16	72.37	75.49	63.59
1935	31.48	37.06	43.57	54.77	62.11	50.99
Mean	37.77	45.81	54.29	68.26	74.25	56.28
Increase	—	+8.04	+16.52	+30.49	+36.48	+18.51

Total produce in lb. per ac.

Year.	Treatment					
	A	B	C	D	E	F
1933	2618	3518	4864	7307	8613	4601
1934	3852	4759	5531	6360	7108	5348
1935	3161	3900	4831	6700	7708	5031
Mean	3210	4059	5075	6789	7810	4993
Increase	—	+849	+1865	+3579	+4600	+1783

6. SULPHATE OF AMMONIA ON BARLEY.

Variety : Pryor ; 80 lb. per ac. sown on oat stubble.

Basal dressing of 2 cwt. per ac. superphosphate.

Treatments:

- A. No nitrogen.
- B. $\frac{1}{2}$ cwt. sulphate of ammonia at seeding.
- C. 1 cwt. sulphate of ammonia at seeding.
- D. 2 cwt. sulphate of ammonia at seeding.
- E. 3 cwt. sulphate of ammonia at seeding.
- F. 1 cwt. sulphate of ammonia in spring.

Design : Treatments arranged in a Latin square.

Area of plot = $1/25$ th acre.

Yields of grain in bushels per ac.

Year.	Treatment					
	A	B	C	D	E	F
1933	28·71	38·33	48·60	60·39	65·16	48·23
1934	24·48	30·68	39·31	51·02	58·77	38·87
1935	32·81	39·25	47·75	61·79	66·08	46·04
Mean	28·67	36·09	45·22	57·73	63·34	44·38
Increase	—	+7·42	+16·55	+29·06	+34·67	+15·71

Total produce in lb. per ac.

Year.	Treatment					
	A	B	C	D	E	F
1933	2773	3834	5121	6639	7386	4931
1934	2333	3006	3972	5419	6399	3895
1935	3086	3867	4756	6138	6744	4519
Mean	2731	3569	4616	6065	6843	4448
Increase	—	+839	+1885	+3334	+4112	+1717

7. VARIETAL RESPONSE OF WHEAT TO SUPERPHOSPHATE AND SULPHATE OF AMMONIA.

Varieties: Ford x Hard Federation = V_1 , Sepoy 324J = V_2 , Gluyas (natural hybrid) = V_3 .

Superphosphate: None = P_0 ; 97 lb. per acre = P_1 ; 194 lb. per acre = P_2 .

Sulphate of Ammonia: None = N_0 ; 100 lb. per acre = N_1 ; 200 lb. per acre = N_2 .

Sown: 2nd July, 1935, on stubble at 83 lb. per acre.

Treatments: All combinations of variety, superphosphate and sulphate of ammonia.

Design: 2 replications of the 27 treatments, each replication being subdivided into 3 blocks of 9 plots to confound a pair of degrees of freedom for second order interaction with soil differences. Area of plot = 1/50th acre.

Yields of grain in bushels per acre. Mean of all varieties ± 1.281 .

Superphosphate	Sulphate of Ammonia			Mean ± 0.740	Increase ± 1.047
	N_0	N_1	N_2		
P_0	42.14	41.74	43.28	42.39	—
P_1	47.39	49.96	52.30	49.89	+7.50
P_2	50.23	52.05	53.85	52.04	+2.15
Mean ± 0.740	46.59	47.92	49.81	48.11	—
Increase ± 1.047	—	+1.33	+1.89	—	—

Mean of all superphosphate ± 1.281 .

Variety	Sulphate of Ammonia			Mean ± 0.740	Increase ± 1.047
	N_0	N_1	N_2		
V_1	40.53	42.66	44.76	42.65	—
V_2	47.81	45.45	50.07	47.78	+5.13
V_3	51.41	55.64	54.60	53.89	+6.11
Mean ± 0.740	46.59	47.92	49.81	48.11	—
Increase ± 1.047	—	+1.33	+1.89	—	—

Mean of all sulphate of ammonia ± 1.281 .

Variety	Superphosphate			Mean ± 0.740	Increase ± 1.047
	P_0	P_1	P_2		
V_1	36.61	44.54	46.81	42.65	—
V_2	41.72	50.20	51.41	47.78	+5.13
V_3	48.83	54.92	57.92	53.89	+6.11
Mean ± 0.740	42.39	49.89	52.04	48.11	—
Increase ± 1.047	—	+7.50	+2.15	—	—

Effects of variety, nitrogen and phosphorus significant; first and second order interactions insignificant. With superphosphate there is a significant falling off in the response to the higher dressing, but not with sulphate of ammonia. With the latter, only the response to the double dressing is significant.

8. PHOSPHORUS AND NITROGEN ON WHEAT GROWN IN VARIOUS ROTATIONS.

Variety : Sepoy ; seed rate 90 lb. per acre.

Superphosphate : None and 2 cwt. per acre. = P.

Sulphate of ammonia : None and 1 cwt. per acre = N.

Manurial treatment : All combinations of the various rates of application of superphosphate and sulphate of ammonia.

Rotation treatment : Wheat after fallow, Early Burt oats, Pryor barley, and Early Brunswick peas.

Design : 60 plots each 4/35th acre divided into two groups of 30 plots. In any year one group of 30 is cropped with wheat while the other group receives the rotational treatments ; in the following year the cropping system is reversed. In each group of 30, the 5 rotations are randomized in 6 blocks. Each rotational plot consists of 4 sub-plots, each 1/35th acre, and the four manurial treatments are randomized in each set of 4 sub-plots.

Yields of grain in bushels per acre ± 1.128 .

Treatment.	Season.	Wheat after					Seasonal mean ± 0.504	Mean ± 0.252
		Fallow.	Peas.	Oats.	Barley.	Wheat.		
None	1931	12.80	21.46	15.32	14.25	14.90	15.75	21.99
	1932	33.83	36.43	30.19	27.20	25.25	30.58	
	1933	32.11	35.85	17.11	15.99	13.74	22.96	
	1934	23.04	29.19	15.19	13.85	11.98	18.65	
	Mean ± 1.050	25.44	30.73	19.45	17.82	16.47		
P	1931	37.16	32.81	20.58	20.24	19.19	26.00	29.63
	1932	50.14	38.69	32.23	30.94	29.19	36.24	
	1933	52.18	42.75	16.62	15.70	14.58	28.37	
	1934	52.45	38.43	16.07	16.97	15.68	27.92	
	Mean ± 1.050	47.99	38.17	21.38	20.96	19.66		
N	1931	20.71	25.37	22.74	18.56	22.19	21.91	26.53
	1932	42.36	34.08	33.93	31.16	31.62	34.63	
	1933	33.76	36.97	20.25	19.18	17.74	25.58	
	1934	28.56	36.09	18.52	20.12	16.70	24.00	
	Mean ± 1.050	31.35	33.13	23.86	22.25	22.06		
PN	1931	38.61	40.24	27.16	29.88	28.29	32.84	35.83
	1932	49.97	46.86	39.06	36.99	37.60	42.10	
	1933	50.70	50.48	22.14	24.18	21.68	33.84	
	1934	53.93	44.84	24.43	25.67	23.80	34.53	
	Mean ± 1.050	48.30	45.61	28.20	29.18	27.84		
Mean ± 0.525		38.27	36.91	23.22	22.56	21.51		28.49
Average increase due to								
P		22.55	7.44	1.93	3.14	3.19		
N		5.91	2.40	4.41	4.43	5.59		
PN		22.86	14.88	8.75	11.36	11.37		

Each increase has a S.E. of ± 1.485 .

The standard errors given in the table have been derived from the main and sub-plot errors obtained from the combined analyses of the seasons. Both the effects of rotations and manurial treatment are significant when compared, respectively, with the significant interactions, rotations x season and treatment x season. The interactions, rotations x treatment and rotations x treatment x season are also significant.

9. EFFECT OF VARYING QUANTITIES OF SEED AND SUPERPHOSPHATE ON CANARY GRASS.

Objective:

To determine the influence of seeding rate and superphosphate on the production of Canary grass (*Phalaris canariensis*).

Seed rates: 8, 16 and 24 lb. per acre. Sown 22nd July, 1935, on bare fallow.

Superphosphate: None = P_0 ; 1 cwt. per acre = P_1 ; 2 cwt. per acre = P_2 .

Treatments: All combinations of superphosphate dressings and seed rates.

Design: 6 randomized blocks of 9 treatments.

Area of plot = 1/37.5 acre.

Yields of seed in cwt. per acre ± 0.198 .

Superphosphate.	8	Seed rate. 16	24	Mean ± 0.114 .	Increase ± 0.162 .
P_0	0.72	1.74	1.89	1.46	—
P_1	2.86	4.28	5.09	4.08	+2.62
P_2	3.72	5.69	7.42	5.61	+1.53
Mean ± 0.114	2.44	3.91	4.80	3.72	—
Increase ± 0.162	—	+1.47	+0.89	—	—

Effects of superphosphate, seed rate and interaction significant. There are significantly greater responses to the higher dressings of superphosphate as the seed rate increases.

Yields of total produce in cwt. per acre ± 0.861 .

Superphosphate.	8	Seed rate. 16	24	Mean ± 0.497 .	Increase ± 0.703 .
P_0	3.96	9.74	10.02	7.91	—
P_1	14.70	21.18	23.52	19.80	+11.89
P_2	20.01	27.73	34.24	27.32	+7.52
Mean ± 0.497	12.89	19.55	22.59	18.34	—
Increase ± 0.703	—	+6.66	+3.04	—	—

Effects of superphosphate, seed rate and interaction significant. There are significantly greater responses to the higher dressings of superphosphate as the seed rate increases.

10. PHOSPHORUS, NITROGEN AND LIME ON WHEAT AFTER FALLOW.

Variety: Sepoy Selection; seed rate 90 lb. per acre, sown 1st July, 1935.

Superphosphate: None = P₀, 1 cwt. per acre = P₁, 2 cwt. per acre = P₂, 3 cwt. per acre = P₃, 4 cwt. per acre = P₄.

Sulphate of ammonia: None = N₀, 1 cwt. per acre = N₁.

Lime: None = Ca₀, 5 cwt. per acre = Ca₁.

Treatments: All combinations of the various rates of application of superphosphate, sulphate of ammonia and lime.

Design: Two replications of the 20 treatments, each replication being subdivided into two sub-blocks of 10 plots to confound the interaction of nitrogen and lime with soil differences. Area of plot = 1/50th acre.

Yields of grain in bushels per acre. Mean of all lime ± 1.204 .

Sulphate of Ammonia.	Superphosphate					Mean	Increase
	P ₀	P ₁	P ₂	P ₃	P ₄	± 0.539 .	± 0.762 .
N ₀	13.44	22.00	26.50	32.50	33.44	25.58	—
N ₁	13.44	21.44	28.88	30.69	31.81	25.25	-0.33
Mean ± 0.852	13.44	21.72	27.69	31.59	32.63	25.41	—
Increase ± 1.204	—	+8.28	+5.97	+3.90	+1.04	—	—

Mean of all sulphate of ammonia ± 1.204 .

Lime.	Superphosphate					Mean	Increase
	P ₀	P ₁	P ₂	P ₃	P ₄	± 0.539 .	± 0.762 .
Ca ₀	10.38	19.06	25.94	28.50	32.19	23.21	—
Ca ₁	16.50	24.38	29.44	34.69	33.06	27.61	+4.40
Mean ± 0.852	13.44	21.72	27.69	31.59	32.63	25.41	—
Increase ± 1.204	—	+8.28	+5.97	+3.90	+1.04	—	—

Superphosphate and lime gave significant increases; all other effects are negligible; significant drop in the response to the higher dressings of superphosphate.

Total produce in cwt. per acre. Mean of all lime ± 1.898 .

Sulphate of Ammonia.	Superphosphate					Mean	Increase
	P ₀	P ₁	P ₂	P ₃	P ₄	± 0.849 .	± 1.201 .
N ₀	17.61	35.36	45.74	54.17	56.05	41.78	—
N ₁	18.82	33.62	49.15	53.44	57.79	42.56	+0.78
Mean ± 1.342	18.21	34.49	47.44	53.81	56.92	42.17	—
Increase ± 1.898	—	+16.28	+12.95	+6.37	+3.11	—	—

Mean of all sulphate of ammonia ± 1.898 .

Lime.	Superphosphate					Mean	Increase
	P ₀	P ₁	P ₂	P ₃	P ₄	± 0.849 .	± 1.201 .
Ca ₀	14.93	30.54	46.74	50.49	55.11	39.56	—
Ca ₁	21.50	38.44	48.15	57.12	58.73	44.78	+5.22
Mean ± 1.342	18.21	34.49	47.44	53.81	56.92	42.17	—
Increase ± 1.898	—	+16.28	+12.95	+6.37	+3.11	—	—

Superphosphate and lime gave significant increases; all other effects are negligible; significant drop in the response to the higher dressings of superphosphate.

11. PHOSPHORUS, NITROGEN AND LIME ON BARLEY AFTER WHEAT.

Variety: Pryor; seed rate 80 lb. per acre, sown 5th July 1935.

Superphosphate: None = P_0 , 1 cwt. per acre = P_1 , 2 cwt. per acre = P_2 , 3 cwt. per acre = P_3 , 4 cwt. per acre = P_4 .

Sulphate of ammonia: None = N_0 , 1 cwt. per acre = N_1 .

Lime: None = Ca_0 , 5 cwt. per acre = Ca_1 .

Treatments: All combinations of the various rates of application of superphosphate, sulphate of ammonia and lime.

Design: Two replications of the 20 treatments, each replication being subdivided into two sub-blocks of 10 plots to confound the interaction of nitrogen and lime with soil differences. Area of plot = 1/50th acre.

Yields of grain in bushels per acre. Mean of all lime ± 2.168 .

Sulphate of Ammonia.	Superphosphate					Mean ± 0.970 .	Increase ± 1.371 .
	P_0	P_1	P_2	P_3	P_4		
N_0	46.73	53.48	57.68	48.00	50.03	51.18	—
N_1	54.53	61.05	65.18	65.33	60.23	61.26	+10.08
Mean ± 1.533	50.63	57.26	61.43	56.66	55.13	56.22	—
Increase ± 2.168	—	+6.63	+4.17	-4.77	-1.53	—	—

Mean of all sulphate of ammonia ± 2.168 .

Lime.	Superphosphate					Mean ± 0.970 .	Increase ± 1.371 .
	P_0	P_1	P_2	P_3	P_4		
Ca_0	47.85	54.83	60.68	56.63	55.50	55.10	—
Ca_1	53.40	59.70	62.18	56.70	54.75	57.35	+2.25
Mean ± 1.533	50.63	57.26	61.43	56.66	55.13	56.22	—
Increase ± 2.168	—	+6.63	+4.17	-4.77	-1.53	—	—

Effects of superphosphate and nitrogen significant; all other effects insignificant; significant drop in the response to the higher dressings of superphosphate.

Total produce in cwt. per acre. Mean of all lime ± 1.917 .

Sulphate of Ammonia.	Superphosphate					Mean ± 0.858 .	Increase ± 1.213 .
	P_0	P_1	P_2	P_3	P_4		
N_0	38.17	44.06	48.61	40.98	42.32	42.79	—
N_1	46.00	52.56	57.65	58.39	52.76	53.43	+10.64
Mean ± 1.356	42.08	48.31	53.13	49.68	47.54	48.11	—
Increase ± 1.917	—	+6.23	+4.82	-3.45	-2.14	—	—

Mean of all sulphate of ammonia ± 1.917 .

Lime.	Superphosphate					Mean ± 0.858 .	Increase ± 1.213 .
	P_0	P_1	P_2	P_3	P_4		
Ca_0	39.91	45.87	52.76	49.48	47.61	47.08	—
Ca_1	44.26	50.76	53.50	49.89	47.47	49.13	+2.05
Mean ± 1.356	42.08	48.31	53.13	49.68	47.54	48.11	—
Increase ± 1.917	—	+6.23	+4.82	-3.45	-2.14	—	—

Effects of superphosphate and nitrogen significant; all other effects negligible; significant drop in response to higher dressings of superphosphate.

12. PHOSPHORUS, NITROGEN AND LIME ON OATS AFTER BARLEY.

Variety : Early Burt ; seed rate 70 lb. per acre, sown 17th June 1935.

Superphosphate : None = P_0 , 1 cwt. per acre = P_1 , 2 cwt. per acre = P_2 , 3 cwt. per acre = P_3 , 4 cwt. per acre = P_4 .

Sulphate of ammonia : None = N_0 , 1 cwt. per acre = N_1 .

Lime : None = Ca_0 , 5 cwt. per acre = Ca_1 .

Treatments : All combinations of the various rates of application of superphosphate, sulphate of ammonia and lime.

Design : Two replications of the 20 treatments, each replication being subdivided into two sub-blocks of 10 plots to confound the interaction of nitrogen and lime with soil differences. Area of plot = 1/50th acre.

Yields of grain in bushels per acre. Mean of all lime ± 2.540 .

Sulphate of Ammonia.	Superphosphate					Mean ± 1.136 .	Increase ± 1.606 .
	P_0	P_1	P_2	P_3	P_4		
N_0	54.66	55.87	56.53	57.37	51.47	55.18	—
N_1	61.22	66.00	66.37	64.03	63.84	64.29	+9.11
Mean ± 1.796	57.94	60.94	61.45	60.70	57.65	59.73	—
Increase ± 2.540	—	+3.00	+0.51	-0.75	-3.05	—	—

Mean of all sulphate of ammonia ± 2.540 .

Lime.	Superphosphate					Mean ± 1.136 .	Increase ± 1.606 .
	P_0	P_1	P_2	P_3	P_4		
Ca_0	55.41	58.31	61.50	61.40	58.03	58.93	—
Ca_1	60.47	63.56	61.40	60.00	57.28	60.54	+1.61
Mean ± 1.796	57.94	60.94	61.45	60.70	57.65	59.73	—
Increase ± 2.540	—	+3.00	+0.51	-0.75	-3.05	—	—

Nitrogen gives the only significant increase in yield; drop in response to higher dressings of superphosphate is not significant.

Total produce in cwt. per acre. Mean of all lime ± 2.513 .

Sulphate of Ammonia.	Superphosphate					Mean ± 1.124 .	Increase ± 1.589 .
	P_0	P_1	P_2	P_3	P_4		
N_0	48.21	48.62	50.69	51.29	46.47	49.06	—
N_1	55.65	58.93	58.66	60.80	59.20	58.65	+9.59
Mean ± 1.777	51.93	53.77	54.68	56.05	52.83	53.85	—
Increase ± 2.513	—	+1.84	+0.91	+1.37	-3.22	—	—

Mean of all sulphate of ammonia ± 2.513 .

Lime.	Superphosphate					Mean ± 1.124 .	Increase ± 1.589 .
	P_0	P_1	P_2	P_3	P_4		
Ca_0	50.76	51.83	54.58	56.18	52.03	53.07	—
Ca_1	53.10	55.71	54.78	55.92	53.64	54.63	+1.56
Mean ± 1.777	51.93	53.77	54.68	56.05	52.83	53.85	—
Increase ± 2.513	—	+1.84	+0.91	+1.37	-3.22	—	—

Nitrogen gives the only significant effect; drop in response to higher dressings of superphosphate is not significant.

13. TOP-DRESSING OF NATURAL PASTURES, WAITE INSTITUTE.

Investigation commenced in 1925, on unimproved natural grassland dominated by *Danthonia* spp.

Technique:

- (a) Plots ten chains by one chain in area, non-replicated, grazed individually by sheep.
- (b) Yields obtained from protected quadrats, $2\frac{1}{2}$ sq. metres in area; eight quadrats per plot.
- (c) Fertilizer treatments, applied annually as follows:
 1. Superphosphate 185 lb. (40 lb. P_2O_5) per acre.
 2. Superphosphate 185 lb. + nitrate of soda 78 lb. ($12\frac{1}{2}$ lb. N) per acre.
 3. Nil.
 4. Ground rock phosphate 103 lb. (40 lb. P_2O_5) per acre.
 5. Basic slag 260 lb. (40 lb. P_2O_5) per acre.

(1) *Effect of fertilizer treatment on yield, 1925-35.*

Cwt. air dry herbage per ac.												
Treatment*.	1925.	1926.	1927.	1928.	1929.	1930.	1931.	1932.	1933.	1934.	1935.	Mean.
1. Superphosphate	27.74	43.20	28.54	39.63	33.70	30.32	47.50	75.66	64.70	38.00	72.90	45.63
2. Super. + Nitrate of Soda	30.69	43.57	27.95	41.81	37.45	39.86	63.12	81.11	63.58	52.44	70.90	50.23
3. Nil	21.76	28.35	18.00	24.31	17.69	20.67	41.43	56.92	51.43	20.23	41.49	31.12
4. Rock Phosphate	18.57	27.16	15.95	27.89	25.63	30.56	52.60	70.34	61.72	43.66	58.25	39.30
5. Basic Slag	25.49	49.15	24.84	35.58	35.31	43.56	58.06	78.25	57.61	48.67	62.72	47.20
Mean	24.85	38.29	23.06	33.84	29.96	32.99	52.54	72.46	59.81	40.60	61.25	42.70

* All phosphate dressings at 40 lb. P_2O_5 per acre. Nitrate of Soda at $12\frac{1}{2}$ lb. N.

(2) *Effect on yield of annual legumes in the pasture, 1925-35.*

Cwt. air dry herbage per ac.												
Treatment.	1925.	1926.	1927.	1928.	1929.	1930.	1931.	1932.	1933.	1934.	1935.	Mean.
1. Superphosphate	20.25	20.17	4.29	23.00	14.45	1.71	6.80	9.35	5.40	1.89	44.53	13.80
2. Super. + Nitrate of Soda	18.35	16.66	0.40	13.78	8.24	0.54	2.79	7.33	2.23	1.17	27.97	9.04
3. Nil	6.57	9.49	1.02	0.90	2.18	0.39	3.56	9.94	4.20	2.34	10.14	4.61
4. Rock Phosphate	5.64	9.18	0.44	3.81	4.74	1.57	5.33	18.01	4.24	1.95	20.69	6.87
5. Basic Slag	14.35	19.12	2.43	4.28	13.30	1.63	5.18	12.58	3.10	0.06	18.63	8.61
Mean	13.03	14.92	1.71	9.15	8.58	1.15	4.73	11.44	3.83	1.48	24.39	8.58

(3) *Effect on stock-carrying capacity, 1928-35.*

Sheep-days of grazing per acre.										
Treatment.	1928.	1929.	1930.	1931.	1932.	1933.	1934.	1935.	Mean.	
1. Superphosphate	900	877	813	1,271	2,421	2,724	1,250	1,953	1,526	
2. Super. + Nitrate of Soda	935	859	1,110	1,551	2,634	3,211	1,518	2,341	1,770	
3. Nil	465	509	592	902	1,764	1,868	754	1,431	1,036	
4. Rock Phosphate	640	603	667	1,072	2,215	2,625	1,051	2,083	1,369	
5. Basic Slag	708	817	1,121	1,355	2,840	3,175	1,370	2,257	1,705	
Mean	729	733	861	1,230	2,375	2,721	1,189	2,013	1,481	

(4) *Correlation between rainfall and yield of pasture, 1925-34.*

Rainfall.	Jan.	Feb.	March.	April.	May.	June.	July.	August.	Sept.	Oct.	Nov.	Dec.
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(a) No fertilizer.

Monthly	+0.09	+0.38	+0.57	+0.73‡	+0.67‡	+0.45	+0.19	-0.06	-0.08	-0.25	-0.81*	-0.50
Bi-monthly	+0.34	+0.53	+0.82*	+0.89*	+0.85*	+0.41	+0.10	-0.09	-0.26	-0.68‡	-0.76‡	
Tri-monthly		+0.47	+0.73‡	+0.93*	+0.96*	+0.85*	+0.44	+0.04	-0.25	-0.63	-0.78†	

(b) Superphosphate.

Monthly	+0.04	+0.39	+0.50	+0.84*	+0.59	+0.43	+0.02	-0.04	-0.28	-0.11	-0.74‡	-0.34
Bi-monthly	+0.33	+0.50	+0.89*	+0.88*	+0.78†	+0.33	-0.02	-0.21	-0.29	-0.54	-0.61	
Tri-monthly		+0.44	+0.78†	+0.91*	+0.95*	+0.72‡	+0.35	-0.18	-0.26	-0.62	-0.58	

Significance of the correlation coefficient: * $P < 0.01$. † $P < 0.02$. ‡ $P < 0.05$.

14. THE YIELD OF A SEEDED PERMANENT PASTURE UNDER DIFFERENT SYSTEMS OF MANAGEMENT.

Pasture Mixture:

Wimmera rye-grass, perennial rye-grass (New Zealand certified), *Phalaris tuberosa*, and subterranean clover (Dwalganup), sown on 3rd June, 1930.

Treatments and Technique:

- (a) Mixture sown in 16 drill strips, 400 x 9 links, with a basal dressing of superphosphate, 2 cwt. per acre per annum.
- (b) Drill strips treated in alternate pairs on the ABBA system, with nitrogen as 2 cwt. sulphate of ammonia per annum.
- (c) Area cross-divided into 4 blocks, each of 16 plots, to give a total of 64 sub-plots. The four blocks subjected to four systems of management as follows:
 - A. Mown four times per annum, and the pasture removed.
 - B. Mown as above, but the pasture returned to the plots for grazing by sheep.
 - C. Grazed by sheep without pre-cutting; sampled for yield from 1932 onwards.
 - D. Cut as hay at conclusion of seasonal growth.

Yield of herbage under different treatments, 1930-35.

(cwt. per acre.)

	1930.	1931.	1932.	1933.	1934.	1935.	Mean.
<i>A. Cut four times each season.</i>							
P	40.95	20.90	38.13	38.36	51.86	57.97	41.36
PN	44.20	31.64	34.89	32.39	49.03	50.88	40.50
Difference due to N	+3.25	+10.74	-3.24	-5.97	-2.83	-7.09	-0.86

B. Cut four times—Material replaced and grazed.

P	28.09	32.41	41.80	25.13	58.93	51.15	39.59
PN	32.02	42.64	45.66	21.88	62.32	49.35	42.31
Difference due to N	+3.93	+10.23	+3.86	-3.25	+3.39	-1.80	+2.72

C. Grazed only.

P	*	*	50.55	28.57	88.33	63.71	57.79
PN	*	*	60.34	25.65	76.52	67.03	57.38
Difference due to N	—	—	+9.79	-2.92	-11.81	+3.32	-0.41

(1932-35 only)

Yield of herbage under different treatments, 1930-35, (cont.).

(cwt. per acre.)

	1930.	1931.	1932.	1933.	1934.	1935.	Mean.
D. Cut as hay.							
P	30.44	24.96	63.74	65.55	48.44	67.39	50.09
PN	37.32	45.58	62.36	61.81	45.80	62.92	52.63
Difference due to N	+6.88	+20.62	-1.38	-3.74	-2.64	-4.47	+2.54

* Records not taken.

The effect of nitrogen on the yield of the principal botanical constituents.

(cwt. per acre.)

	<i>Lolium.</i>		<i>Phalaris.</i>		<i>Trifolium.</i>		Total Sown Species.	
	P	PN	P	PN	P	PN	P	PN
Systematically cut	19.67	32.61	77.87	77.13	68.08	36.26	165.62	146.00
Cut and grazed	42.32	61.77	86.79	72.79	18.61	5.53	147.72	140.09
Grazed	52.79	73.71	115.07	110.79	22.13	5.18	189.99	189.68
Cut for hay	42.61	59.33	184.70	151.72	4.12	0.83	231.43	211.88

15. PHOSPHORUS AND NITROGEN ON THE YIELD AND BOTANICAL COMPOSITION OF TWO SWARDS, WAITE INSTITUTE.

Technique:

- (a) Two pasture mixtures sown in autumn 1932 and consisting respectively of (i) *Phalaris tuberosa* and first early subterranean clover, (ii) perennial rye-grass, *Phalaris tuberosa* and first early subterranean clover.
- (b) Four fertilizer treatments, in the form of a Latin square, superimposed on each sward in 1933. Size of plots 80 x 125 links. Fertilizer treatment (i) unfertilized, (ii) superphosphate 2 cwt. per acre in autumn, (iii) Sulphate of Ammonia 1 cwt. per acre in autumn and again in spring, (iv) Superphosphate 2 cwt. per acre + Sulphate of Ammonia 2 cwt. per acre, as above.
- (c) Yield of pasture measured prior to each grazing by cuts from 4 unprotected quadrats per plot, each 10 x 5 links. Two to four grazings per annum, depending on seasonal conditions.
- (d) Yield as hay measured by cuts from a single protected quadrat, 2½ square metres in surface area, from each plot.
- (e) Total yields of dry matter and botanical composition determined from pasture sample

(1) Total Yields of Dry Matter under grazing (lb. per acre) and Percentage Increase over Unfertilized Plots due to Fertilizer Treatments.

	Phalaris Section.			Lolium-Phalaris Section.		
	1933.	1934.	1935.	1933.	1934.	1935.
Nil	5619·5	3620·1	7041·1	3695·3	2550·6	6177·9
P	6520·5	4000·6	7763·7	5026·4	3271·8	8349·3
% increase	16·0	10·5	10·3	36·0	28·3	35·1
N	5773·2	4399·6	7385·4	4271·9	3175·6	5715·5
% increase	2·7	21·5	4·9	15·6	24·5	—7·5
PN	6887·0	5531·0	9170·1	5257·8	3732·0	7277·8
% increase	22·6	52·8	30·2	42·3	46·3	17·8

(2) Yield of Sown Grasses (lb. per acre) under Grazing.

	Phalaris Section.				Lolium-Phalaris Section.							
	Nil.	P	N	PN	Nil		P		N		PN	
					Ph.	Lol.	Ph.	Lol.	Ph.	Lol.	Ph.	Lol.
1933	3,807·2	4,365·7	4,679·3	6,179·5	62·7	1,381·9	79·6	2,183·0	96·6	3,133·3	103·0	3,704·2
1934	3,348·5	3,702·9	4,092·5	5,787·9	603·5	1,012·3	968·7	1,385·2	677·6	2,097·1	869·4	2,164·4
1935	4,043·8	4,385·8	5,396·2	7,292·6	1,528·0	918·5	2,749·8	1,715·4	1,216·1	1,936·0	1,726·9	2,463·7

(3) Total Yields of Dry Matter as Hay (lb. per acre).

	Phalaris Section.			Lolium-Phalaris Section.		
	1933.	1934.	1935.	1933.	1934.	1935.
Nil	5375·1	3615·0	5571·8	3839·1	2220·0	5042·4
P	6263·8	4150·2	6395·8	4699·5	3812·6	6335·3
N	5971·3	3875·9	6775·8	4187·3	2666·2	5006·6
PN	5770·0	4918·0	6997·5	4545·9	3353·9	6055·4

16. SULPHATE OF AMMONIA ON SEEDED PASTURE AT MOUNT BARKER, 1933-35.

Trial laid down on fallow land in April 1933 consisting of two randomized blocks of six treatments, viz.:

(1) <i>Trifolium subterraneum</i>	}	Phosphate
(2) <i>Lolium perenne</i>		
(3) <i>Trifolium subterraneum</i> + <i>Lolium perenne</i>		
(4) <i>Trifolium subterraneum</i>	}	Phosphate + Nitrogen
(5) <i>Lolium perenne</i>		
(6) <i>Trifolium subterraneum</i> + <i>Lolium perenne</i>		

All seed rates at 5 lb. per acre.

T. subterraneum = Mount Barker strain.

L. perenne = New Zealand certified rye-grass.

Phosphate—2 cwt. per acre per annum applied in April.

Phosphate + Nitrogen—2 cwt. per acre per annum applied in April + 4 cwt. per acre per annum Sulphate of Ammonia, in four applications of 1 cwt. per acre.

Manurial treatments separately grazed by sheep immediately after cutting.

Herbage hand-separated and oven-dried at 102° C.

Seasonal yield of pasture. Means of all treatments. Oven-dry weights at 102° C.

Date of cut.	Cut No.	Yield cwt. per ac.	% of Mean.
2nd October, 1933	1	20·49	108·7
20th November, 1933	2	13·75	72·9
Total yield for 1933	..	34·24	
2nd July, 1934	3	8·86	47·0
29th August, 1934	4	9·48	50·3
10th October, 1934	5	14·22	75·4
2nd December, 1934	6	31·28	165·9
Total yield for 1934	..	63·84	
1st July, 1935	7	18·37	97·4
3rd September, 1935	8	16·85	89·4
15th October, 1935	9	25·10	133·1
12th December, 1935	10	30·14	159·9
Total yield for 1935	..	90·46	

General Mean = 18·85 cwt. per acre = 100·00%.

S.E. of Mean = 0·968 cwt. per acre = 5·14%.

17. ESTABLISHMENT OF PERMANENT PASTURE WITH VARYING COVER CROP AND FERTILIZER TREATMENT ON A MALLEE-HEATH SOIL, TINTINARA, S.A.

Technique:

- (a) Pasture mixture of $\frac{1}{2}$ lb. Wimmera rye-grass, 2 lb. *Phalaris tuberosa*, 2 lb. lucerne, 2 lb. Mount Barker subterranean clover, 2 lb. Dwalganup early subterranean clover, sown on 26th April, 1935, on fallowed land following first crop after clearing.
- (b) Pasture seeded under (1) no cover crop; (2) barley ($\frac{1}{2}$ bush.); (3) oats ($\frac{1}{2}$ bush.); (4) peas (1 bush.).
- (c) Fertilizer treatments— P_1 , $\frac{3}{4}$ cwt. superphosphate per acre; P_2 , $1\frac{1}{2}$ cwt. superphosphate per acre; P_1N_1 , $\frac{3}{4}$ cwt. superphosphate + $\frac{3}{4}$ cwt. sulphate of ammonia per acre; P_2N_1 , $1\frac{1}{2}$ cwt. superphosphate + $\frac{3}{4}$ cwt. sulphate of ammonia per acre.
- (d) Fertilizer treatments in a 4 x 4 Latin square with cover crop treatment as 4 randomized plots within each fertilizer plot. Total plots 64, each 50 x 33-1/3rd links. Complete replications 4.
- (e) Plots sown to oats and barley again subdivided into three sub-plots, which were cut (a) for grain, (b) as hay, (c) three times to simulate grazing.
- (f) Cover crops cut over whole plot. Yields of pasture obtained by taking four samples each 5 x 2 $\frac{1}{2}$ links per unit plot.

Mean yields of cover crops in the seeding year.

Grain yields in bushels per acre, air-dry. All other yields as cwt. dry matter per acre.

Manner of utilization.	Barley.			Oats.		Peas.
	Grain (bush.).	Hay (cwt.).	Pasture (cwt.).	Hay (cwt.).	Pasture (cwt.).	Grain (bush.).
A. $\frac{3}{4}$ cwt. super	13.68	18.67	11.36	19.45	10.99	8.43
B. $1\frac{1}{2}$ cwt. super	20.49	27.42	14.35	23.87	12.33	11.95
C. $\frac{3}{4}$ cwt. super + $\frac{3}{4}$ cwt. sulph. ammonia	17.71	26.79	15.09	27.41	13.97	7.46
D. $1\frac{1}{2}$ cwt. super + $\frac{3}{4}$ cwt. sulph. ammonia	24.83	30.07	17.06	28.68	15.90	10.33

Mean establishment of pasture species in the seeding year.

Species.	Seeds Mixture.					Cover Crops.		
	Wimmera rye-grass, 4	<i>Phalaris</i> <i>ruberosa</i> , 2	Lucerne, 2	Mt. Barker sub. clover, 2	Dwalganus sub. clover, 2	Barley, 25	Oats, 20	Peas, 60
Seed rate (lb.).								
<i>Viable seeds sown per sq. link</i>	0.77	5.34	3.72	1.16	0.77	2.55	3.28	1.46
<i>Establishment.</i>								
1. <i>No cover crop:</i>								
Plants per sq. link	0.69	2.91	2.79	0.94	0.77	—	—	—
% estab- lishment	89.6	54.5	75.0	81.0	99.4	—	—	—
2. <i>With barley:</i>								
Plants per sq. link	0.54*	2.40*	2.32	0.92	0.93	1.97	—	—
% estab- lishment	70.1	44.9	62.4	79.3	120.8†	77.2	—	—
3. <i>With oats:</i>								
Plants per sq. link	0.62	2.17*	2.51	1.04	0.82	—	2.65	—
% estab- lishment	80.5	40.6	67.4	89.6	106.5†	—	80.8	—
4. <i>With peas:</i>								
Plants per sq. link	0.72	2.68	2.66	0.87	0.69	—	—	0.62
% estab- lishment	93.5	50.2	71.5	75.0	89.6	—	—	42.5

* Significant depression due to cover crop.

† The counts here, which are over 100 per cent., indicate that a higher soil germination occurred than was obtained in the laboratory.

Mean occurrence of permanent species in the second year.

Species.	No cover crop.	Barley			Oats			Peas.
		as grain.	as hay.	as pasture.	as grain.	as hay.	as pasture.	
<i>Phalaris tuberosa</i> :								
Plants per sq. link	0.63	0.36	0.41	0.46	0.31	0.36	0.41	0.73
% survival	21.6	15.0	17.1	19.2	14.3	16.6	18.9	27.2
<i>Lucerne</i> :								
Plants per sq. link	1.46	1.19	1.17	1.17	1.20	1.18	1.20	1.44
% survival	52.3	51.3	50.4	50.4	47.8	47.0	47.8	54.1
<i>Subterranean clover</i> :								
Plants per sq. link	7.8	10.5	7.7	9.0	9.1	7.2	8.7	4.8
% increase	356	468	316	386	389	287	368	208

Mean yields of sown pasture in the seeding year.

(Cwt. dry matter per acre.)

Treatment.	No cover crop.	Barley			Oats			Peas.
		as grain.	as hay.	as pasture.	as grain.	as hay.	as pasture.	
(a) Sown grasses.								
A. $\frac{3}{4}$ cwt. super	9.35	0.51	0.68	0.73	1.19	1.29	0.54	8.78
B. $1\frac{1}{2}$ cwt. super	16.63	0.46	0.57	0.91	2.58	1.46	1.07	8.38
C. $\frac{3}{4}$ cwt. super + $\frac{3}{4}$ cwt. sulph. ammonia	13.21	0.41	0.37	0.37	1.33	1.10	0.55	7.57
D. $1\frac{1}{2}$ cwt. super + $\frac{3}{4}$ cwt. sulph. ammonia	13.61	0.72	0.18	1.76	1.87	0.94	1.83	12.58
Mean	13.20	0.53	0.45	0.94	1.74	1.20	1.00	9.33
(b) Sown legumes.								
A. $\frac{3}{4}$ cwt. super	9.62	10.99	9.25	9.81	12.84	7.84	8.71	2.99
B. $1\frac{1}{2}$ cwt. super	6.66	11.52	10.08	14.79	7.52	6.81	9.93	2.45
C. $\frac{3}{4}$ cwt. super + $\frac{3}{4}$ cwt. sulph. ammonia	8.52	8.62	6.53	7.25	11.02	5.44	8.66	3.10
D. $1\frac{1}{2}$ cwt. super + $\frac{3}{4}$ cwt. sulph. ammonia	9.62	9.54	9.83	6.25	13.42	7.49	8.14	2.65
Mean	8.60	10.17	8.92	9.52	11.20	6.90	8.86	2.80

18. APPLICATION OF PHOSPHATE TO A SUBTERRANEAN CLOVER PASTURE.

Investigation commenced at Meadows, South Australia, in 1934. Soil type, a podsolized sand—the Meadows sand type. Mean annual rainfall, 36 inches.

Natural vegetation—sclerophyll forest, with pink gum (*Eucalyptus fasciculosa*) and tea-tree (*Leptospermum myrsinoides*).

Technique:

An area of approximately one acre, which had been burnt, was cleared of scrub and ploughed in March 1934. On 17th April, 100 plots, each 20 x 25 links were laid out in the form of a 10 x 10 Latin square and all were sown subterranean clover 5 lb. per acre and *Phalaris tuberosa* $\frac{1}{2}$ lb. per acre.

Yields obtained by sampling with a sheep-shearing machine: four samples 5 x 2 $\frac{1}{2}$ links per plot. Sampling followed by drastic grazing and close scything. Total yields are from one cut in the first season and from two cuts, one in September and one in November, in the second season.

Fertilizer treatment:

1934.	1935.
1. Nil.	Nil.
2. 1 cwt. superphosphate per acre.	1 cwt. superphosphate per acre.
3. 4 cwt. superphosphate per acre.	Nil.
4. Rock phosphate equivalent to 2 cwt. super per acre.	Nil.
5. 2 cwt. superphosphate per acre, 12 weeks after seeding.	Nil.
6. 2 cwt. superphosphate per acre at seeding.	Plots re-grouped to receive:
7. 2 cwt. superphosphate per acre at seeding + 5 cwt. slaked lime per acre.	a. Nil.
8. do. + 1 cwt. sulphate of potash per acre.	b. $\frac{1}{2}$ cwt. superphosphate per acre.
9. do. + $\frac{1}{2}$ cwt. sulphate of ammonia per acre.	c. 1 cwt. superphosphate per acre.
10. Basic slag equivalent to 2 cwt. superphosphate per acre.	d. 2 cwt. superphosphate per acre.
	e. 4 cwt. superphosphate per acre.

(1) Seedling establishment.

(a) Number of plants per sq. link.

	Nil.	Super. 2 cwt.	Super. 2 cwt. + Sulp. Amm. $\frac{1}{2}$ cwt.	Mean.	Standard Error No.	%.
Subterranean clover	1.83	1.95	2.29	2.02	0.06	3.11
<i>Phalaris tuberosa</i>	0.81	1.01	1.07	0.96	0.06	6.49

(b) *Percentage establishment.*

	Nil.	Super. 2 cwt.	Super. 2 cwt. + Sulp. Amm. ½ cwt.	Mean.
Subterranean clover	57.9	61.7	72.5	63.9
<i>Phalaris tuberosa</i>	46.5	58.0	61.5	55.2

(2) *Yields of Dry Matter in the First Year.*

(cwt. dry matter per acre.)

Species.	Superphosphate.					Treatment.		Basal 2 cwt.			Standard Error (cwt.).
	Nil.	1 cwt.	2 cwt.	4 cwt.	2 cwt. in winter.	Basic Slag (equiv. 2 cwt. super- phosphate).	Rock Phosph. (equiv. 2 cwt. super- phosphate).	+S.A. ½ cwt.	+S.K. 1 cwt.	+Lime 5 cwt.	
Sub. Clover	4.33	19.80	27.01	32.67	23.82	28.68	6.57	29.92	28.86	26.20	1.88
<i>Phalaris tuberosa</i>	0.08	1.29	1.66	2.03	1.68	0.97	0.12	2.71	2.45	2.91	0.30
Miscel- laneous	2.08	3.73	4.51	2.37	2.99	2.63	2.70	3.10	3.09	2.65	0.52
Total yield	6.49	24.82	33.18	37.07	28.49	32.28	9.39	35.73	34.40	31.76	1.88

Standard Error (Total Yield) = 6.86%.

(3) *Yields of Dry Matter in the Second Year.*

(cwt. dry matter per acre.)

Species.	1934. Nil.	Treatment.										Standard Error (cwt.).
		Rock Phos.	Super.	Super. 4 cwt.	Super. 1 cwt.	Superphosphate						
			2 cwt. winter			2 cwt. per acre or equivalent.	2 cwt.	½ cwt.	1 cwt.	2 cwt.	4 cwt.	
Sub. Clover	1935. Nil.	Nil.	Nil.	Nil.	1 cwt.	Nil.	½ cwt.	1 cwt.	2 cwt.	4 cwt.		
	2.61	5.07	28.42	33.02	39.06	26.16	31.53	38.18	38.71	44.78	—	
<i>Phalaris tuberosa</i>	1.64	0.96	4.97	9.84	3.79	2.51	6.78	6.38	10.58	12.19	—	
Miscellaneous	1.89	1.71	3.89	4.76	3.62	4.39	4.29	5.93	6.38	5.93	—	
Total Yield	6.14	7.74	37.28	47.62	46.47	33.06	42.60	50.49	55.67	62.90	2.35	

Standard Error (Total Yield) = 3.74%.

19. YIELD TRIAL OF NEW CROSSBRED WHEATS AT THE
WAITE INSTITUTE, 1933.

Technique:

1. Four randomized replications of 16 strains including four varieties.*
2. Sown 16th June on fallow with 78 lb. seed and 2 cwt. superphosphate per acre.
3. Rainfall (seeding to harvest) 11·64 inches.

Yield results:

Strain Number.	Strain or Variety.	Mean Yield. bush. per acre.	Days to Heading.
33- 36	Gluyas x Minister	53·06	123
33-112	Early Sepoy Selection	51·06	123
33-101	Sepoy Selection	50·87	125
33-106	Sepoy Selection	50·79	126
33-108	Gluyas x Minister	49·35	123
33- 33	Gluyas x Minister	49·32	121
33-115	*Free Gallipoli	49·12	131
33-108	Gluyas x Unknown	47·38	123
33-113	*Sepoy 324J	47·00	135
33-102	Canberra x Gluyas	44·58	113
33-116	*Late Gluyas	44·43	120
33-114	Sepoy Selection (R.R.)	43·37	122
33-111	Gluyas Selection	43·33	123
33-110	Indian E x Gluyas	41·85	124
33-109	Canberra x Gluyas	41·17	120
33-104	*Early Gluyas	36·74	118

Significant difference between mean yields 4·02 bush. per acre.

20. YIELD TRIAL OF NEW CROSSBRED WHEATS AT THE WAITE INSTITUTE, 1934.

Technique:

1. Four randomized replications of 11 strains including Sepoy and Nabawa as control varieties.
2. Sown on fallow at two dates, 21st May and 16th July, with 72 lb. seed and 2 cwt. superphosphate per acre.
3. Rainfall (seeding to harvest) : Early sown, 17.78 in.; late sown, 15.72 in.

Yield results:

Strain Number.	Strain or Variety.	Sown May 21. bush. per ac.	Days to Heading.	Sown July 16. bush. per ac.	Days to Heading.
33-113	Sepoy 324J	45.50	153	51.57	106
33-101	Sepoy Selection	45.26	142	47.45	98
33-112	Early Sepoy Selection	44.08	133	48.00	94
33- 33	Gluyas x Minister	50.02	136	41.47	97
33- 29	Nabawa x Hard Federation	41.42	115	49.70	88
34- 13	Ford x Hard Federation	40.13	136	44.03	97
33-108	Gluyas x Unknown	43.60	127	40.13	96
33-114	Sepoy Selection (R.R.)	38.00	133	44.19	97
33-102	Gluyas x Minister	45.79	133	42.37	98
—	Nabawa	38.90	136	40.51	99
33-102	Canberra x Gluyas	40.19	118	33.66	92
Significant difference between mean yields		3.18 bush.		4.41 bush.	

21. YIELD TRIAL OF NEW CROSSBRED WHEATS AT THE WAITE INSTITUTE, 1935.

Technique:

1. A. Four randomized replications of 10 strains sown mid-season.
 B. Four randomized replications sown late with the varieties Sepoy, Nabawa and Early Gluyas as control varieties in both series A and B.
2. A. Sown 4th June on fallow with 70 lb. seed and 2 cwt. superphosphate per acre.
 B. Sown 2nd July on fallow with 70 lb. seed and 2 cwt. superphosphate per acre.
3. Rainfall (seeding to harvest) : A—15·18 in.; B—12·86 in.

Yield results:

A. Sown 4th June:

Strain Number.	Strain or Variety.	Mean Yield. bush. per acre.	Days to Heading.
33-101	Sepoy Selection	52·9	135
34- 41	Federation x Minister	48·9	138
33-113	Sepoy 324J	44·9	145
34- 13	Ford x Hard Federation	41·5	131
33-104	Early Gluyas	38·8	122
—	Nabawa	37·1	130
34- 24	Nabawa x Hard Federation	34·9	139
34- 14	Sepoy x Federation	33·8	141
33- 36	Gluyas x Minister	33·4	130
33-106	Sepoy Selection	29·4	132

Significant difference between
mean yields

3·8 bush.

B. Sown 2nd July:

33-108	Gluyas x Unknown	36·6	99
33-113	Sepoy 324J	34·7	111
—	Nabawa	33·0	100
34- 13	Ford x Hard Federation	32·6	100
33-112	Early Sepoy	31·6	99
34- 19	Nabawa x Hard Federation	30·9	91
34- 18	Nabawa x Hard Federation	29·7	91
33-106	Sepoy Selection	26·3	101
34- 9	Hard Federation x Gluyas	23·5	92
33-104	Early Gluyas	22·1	98

Significant difference between
mean yields

2·9 bush.

22. YIELD TRIAL OF NEW CROSSBRED WHEATS AT YURGO, 1935.

Technique:

1. Four randomized replications of 7 strains.
2. Sown May 30th on fallow with 60 lb. seed and 1 cwt. superphosphate per acre.

Yield results:

Strain Number.	Strain.	Yield. bush. per acre.
33-101	Sepoy Selection	30.4
33-106	Sepoy Selection	27.2
33- 33	Gluyas x Minister	26.0
34- 26	Nabawa x Hard Federation	25.6
33-114	Sepoy (Rust-resistant)	25.3
33- 13	Ford x Hard Federation	23.3
34-153	Nabawa	23.0
Significant difference between mean yields		2.7 bush.

